NASA Contractor Report 145362

A COMPUTER PROGRAM FOR CALCULATING AERODYNAMIC CHARACTERISTICS OF LOW ASPECT-RATIO WINGS WITH PARTIAL LEADING-EDGE SEPARATION

Sudhir C. Mehrotra and C. Edward Lan

THE UNIVERSITY OF KANSAS CENTER FOR RESEARCH, INC.
Lawrence, KS 66045

NASA Grant NSG-1046
May 1978

(NASA-CR-145362) A COMPUTER PROGRAM FOR CALCULATING AERODYNAMIC CHARACTERISTICS OF LOW ASPECT-RATIO WINGS WITH PARTIAL LEADING-EDGE SEPARATION (Kansas Univ. Center for Research, Inc.) 132 p HC A07/MF A01 N80-26268

Unclas
G3/02 23579

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

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Sudhir C. Mehrotra

and

C. Edward Lan

Technical Report CRINC-FRL-266-2

April 1978

The Flight Research Laboratory
The University of Kansas Center for Research, Inc.
Lawrence, Kansas 66045

Prepared under NASA Grant NSG 1046
for
Langley Research Center
National Aeronautics and Space Administration

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LIST OF SYMBOLS

Symbols	Description	Dimensions
b	Wing span	m (ft)
c	Local chord	m (ft)
C_R	Root chord	m (ft)
M	Number of spanwise strips plus one	
N	Number of bound elements	
x,y,z	Wing rectangular coordinate system with x in the streamwise direction and y to the right	m (ft)
Greek		
α	Angle of attack	deg
Subscripts		
cp	Control point	
i	Chordwise bound element number	
j	Spanwise strip number	
k	Chordwise bound element number	
ℓ	Leading-edge	

1. INTRODUCTION

This document describes in detail the necessary information for using a computer program to predict distributed and total aerodynamic characteristics for low aspect-ratio wings with partial leading-edge separation. This program is based on the numerical method developed in reference 1. The flow is assumed to be steady and inviscid. The wing boundary condition is formulated by the Quasi-Vortex-Lattice method. The leading-edge separated vortices are represented by discrete free vortex elements which are aligned with the local velocity vector at mid-points to satisfy the force free condition. The wake behind the trailing-edge is also force free. The flow tangency boundary condition is satisfied on the wing, including the leading- and trailing-edges.

The program is restricted to delta wings with zero thickness and no camber. It is written in Fortran language and runs on CDC 6600 Computer.

2. COMPUTER PROGRAM DESCRIPTION

2.1 PROBLEM DEFINITION

In steady symmetric flight at a high angle of attack, the flow over a thin low aspect-ratio highly sweptback wing separates along the leading-edge and the tips. In the following, only delta wings are considered. The wing can be represented by a bound vortex sheet, across which there exists a pressure difference, and the separated flow along leading-edges by force free vortex sheets, across which there is no pressure difference. In the present method, the Quasi-Vortex-Lattice method (reference 2) is used to simplify the induced velocity expressions due to the bound vortex sheet and discrete force free vortex elements for separated vortex sheets. The following boundary conditions are imposed on the flow model:

a. The flow must be tangential to the wing surface.

b. The leading-edge boundary condition and the trailing-edge Kutta condition are to be satisfied.

c. The vortex elements over the wing and wake behind the trailing-edge are force free.

This is a non-linear problem because the strengths of the wing bound vortices and free vortices, and the locations of the free vortex elements are unknown. Thus, the problem is solved by an iterative method.

2.2 PROGRAM CAPABILITIES

This computer program provides a theoretical method for determining the aerodynamic characteristics of low aspect-ratio thin delta wings without camber, with partial leading-edge separation. The following is a list of the aerodynamic characteristics the program calculates:

a. Spanwise and chordwise ΔC_p distributions

b. Spanwise distribution of sectional lift, induced-drag and pitching moment coefficients.

c. Total lift, induced-drag, pitching-moment and leading-edge thrust coefficients.

2.3 GEOMETRY DESCRIPTION

The origin of the rectangular coordinate system is at the wing apex. The wing lies in the x-y plane and the x-axis is taken along the wing center-line The wing span is given by b and the surface area S.

2.3.1 WING GEOMETRY

The location of bound- and trailing-vortex elements for a typical case are shown in figure 1. The x-location of bound elements is given by the cosine law and is illustrated in figure 1.

$$x_i = x_\ell + \frac{c}{2}\left(1 - \mathrm{Cos}\left(\frac{2i - 1}{2N}\pi\right)\right), \qquad (1)$$

$$i = 1,2,\text{---}N$$

where x_ℓ is the leading-edge x-coordinate, c is the chord and N is the number of bound elements in a chordwise direction. The spanwise location of trailing elements is given by,

$$y_j = \frac{b}{4}\left(1 - \mathrm{Cos}\left(\frac{2j - 1}{2M}\pi\right)\right), \qquad (2)$$

$$j = 1,2,\text{---}M$$

where b is the span and M is the number of legs of trailing vorticity, which is one higher than the number of spanwise strips of bound elements. The locations of control points are given by,

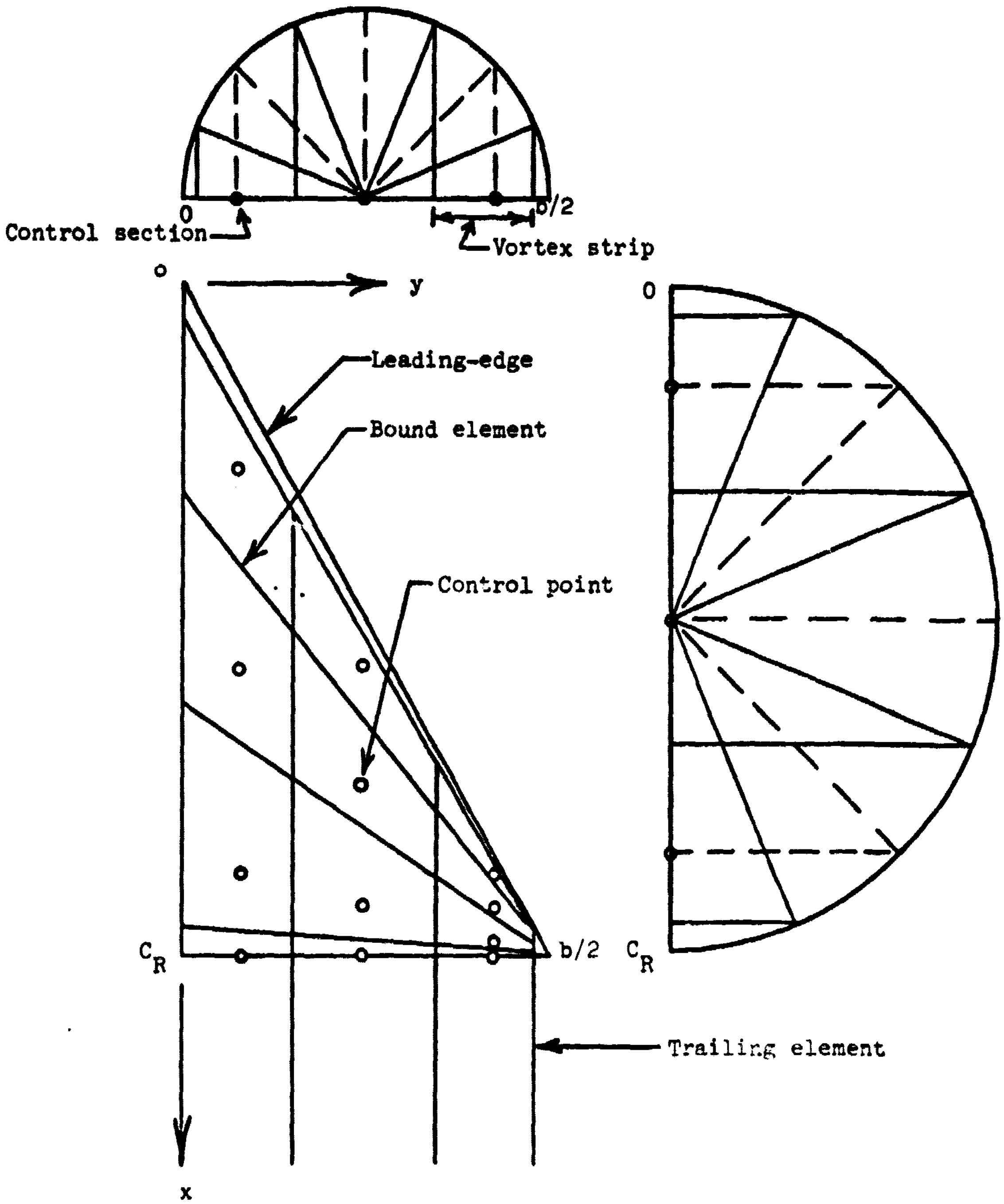

Figure 1. Wing geometry without leading-edge vortex system

$$x_{cp_k} = x_{\ell_j} + \frac{c_j}{2}\left(1 - \cos\left(\frac{\pi k}{N}\right)\right) , \tag{3}$$

$$k = 0,1,2,\text{---}N$$

$$y_{cp_j} = \frac{b}{4}\left(1 - \cos\left(\frac{\pi j}{M}\right)\right) , \tag{4}$$

$$j = 1,2,\text{---}(M - 1)$$

where x_{ℓ_j} and c_j are the leading-edge x-coordinate and chord at y_{cp_j} respectively.

It has been found numerically that the aerodynamic characteristics depended on the number of spanwise strips, i.e. M of equation (2). Therefore, a parametric study has been made to find a relation between the aspect ratio and the number of spanwise strips for reasonably accurate results (Fig. 2) (Section 3 of ref. 1). It is to be noted that as the aspect ratio is decreased, the number of spanwise strips has to be increased. This is due to the fact that the spanwise variation of aerodynamic characteristics, such as pressure coefficient and thrust coefficient, is large for small aspect ratio wings. This study was performed by matching the lift coefficients obtained by using the present method to those obtained by using suction analogy (ref. 3) at one angle of attack.

2.3.2 LEADING-EDGE VORTEX SYSTEM GEOMETRY

The leading-edge vortex system is superimposed on the regular quasi-vortex-lattice grid. A typical vortex element is shown by points A through J in figure 3. These points are connected by a series of short straight segments. The initial location of these segments is shown by dashed lines and final

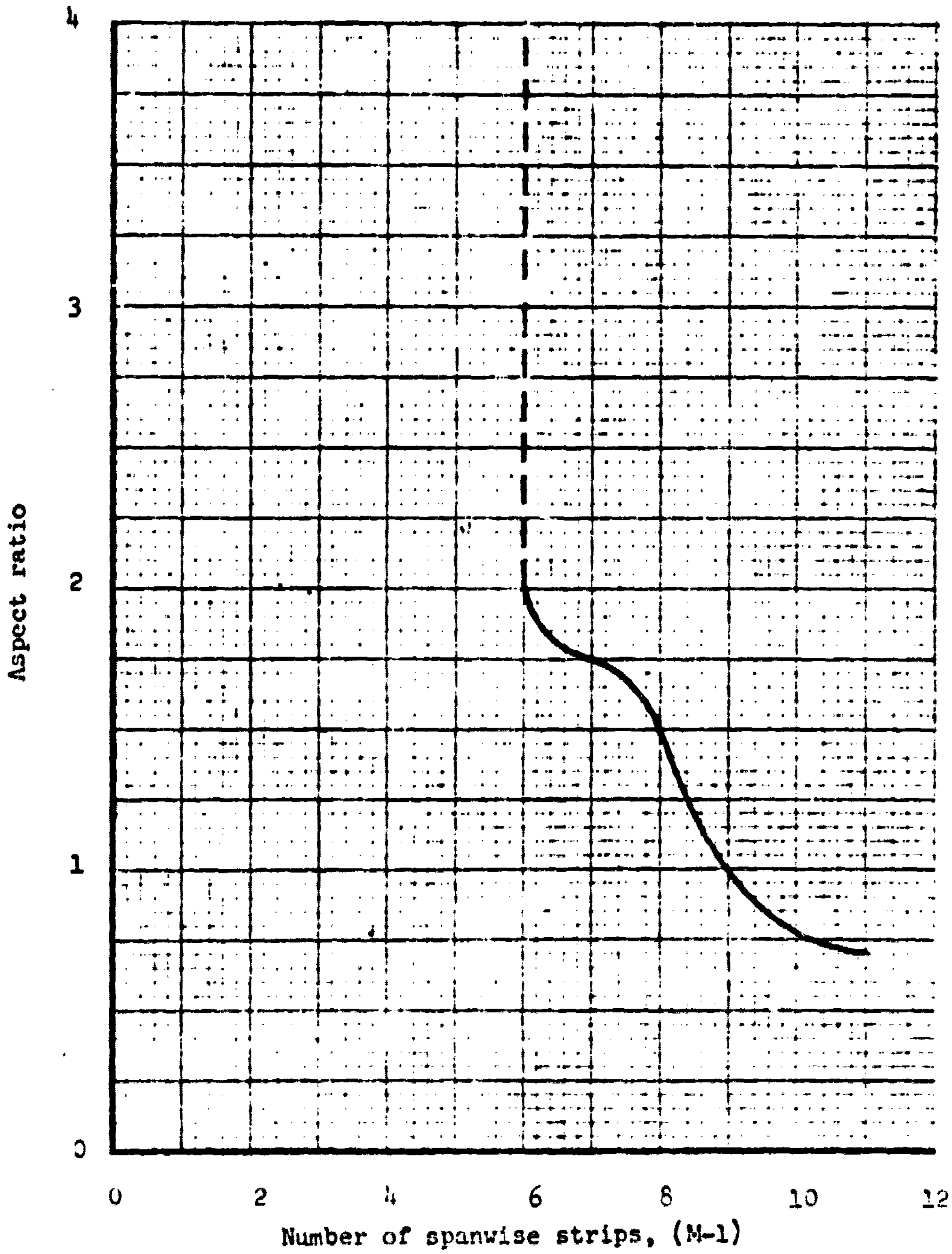

Figure 2. Variation of number of spanwise strips with aspect ratio

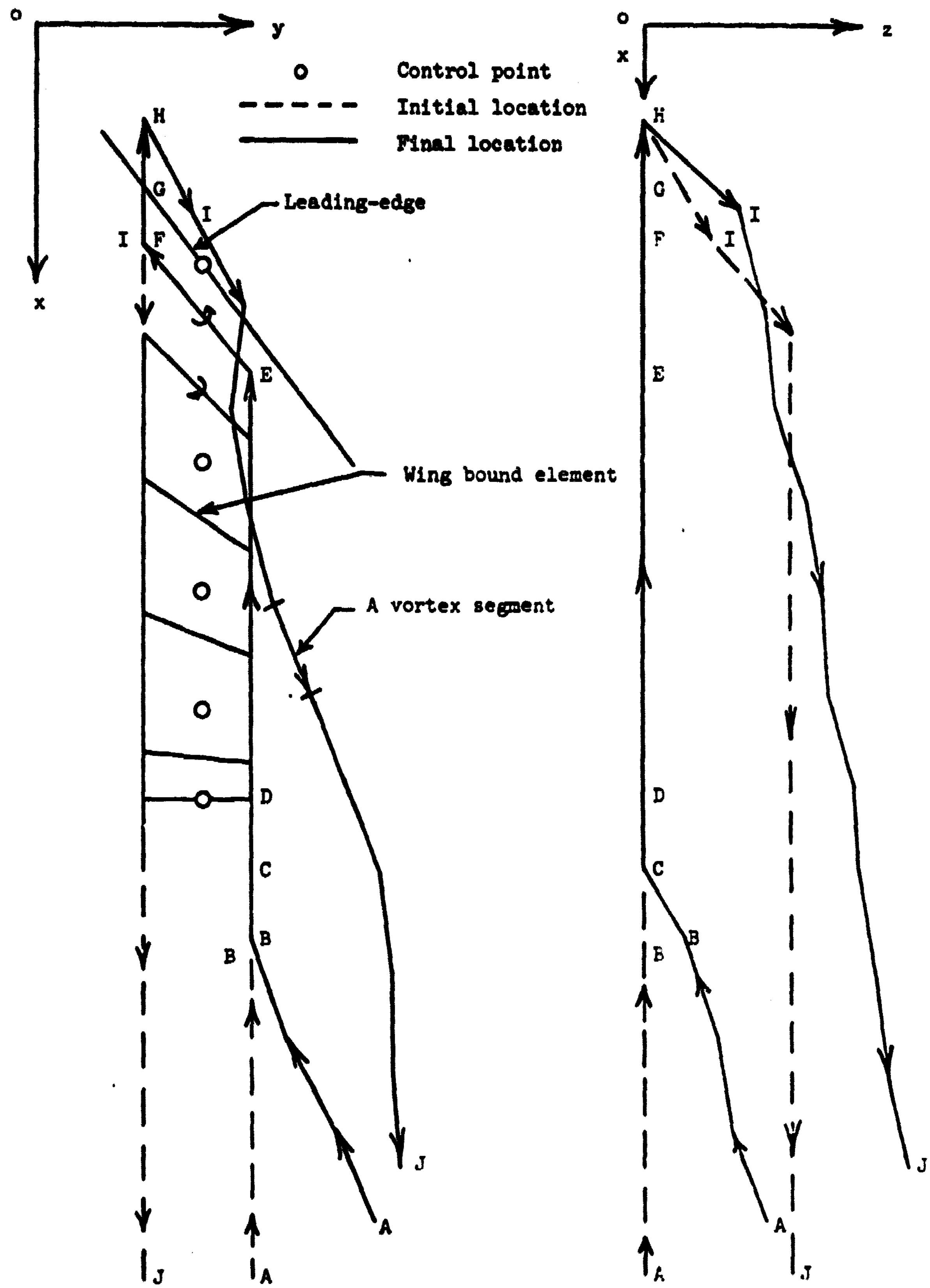

Figure 3. A typical vortex element of leading-edge vortex system

location by solid lines. These segments have the following characteristics;

a. Points A through E lie along a wing trailing vortex element. Initially point A is one root chord away from the trailing-edge in the downstream direction and the line segments between A and D are parallel to the axis of symmetry. The line segments between points A and B are of equal length. In the final converged position these segments are aligned in the direction of the local velocity vector. The segments B-C and C-D are 0.1 C_R long. B-C is allowed to move only in the vertical direction whereas C-D is fixed in the wing plane because the flow is tangential to the trailing-edge. Segment D-E is also fixed in the wing plane.

b. Points E, F, G and H also lie in the wing plane. The location of segment E-F is ahead of the wing first bound element and is given by,

$$x_E = x_{\ell_E} + \frac{c_E}{2} (1 - \text{Cos}(\frac{\pi}{2(N + 1)})) \tag{5.a}$$

$$x_F = x_{\ell_F} + \frac{c_F}{2} (1 - \text{Cos}(\frac{\pi}{2(N + 1)})) \tag{5.b}$$

where the subscripts E and F refer to the points under consideration. The above two equations are similar to equation (1). It is to be noted that segment E-F is located at the first bound element for a grid of (N + 1) bound elements in a chordwise direction. The segments F-G and G-H are of the same length and point G lies on the leading-edge. The segment G-H is fixed in the wing plane due to the leading-edge boundary condition.

c. The initial location of point I is given by,

$$x_I = x_F \tag{6.a}$$

$$y_I = y_F \tag{6.b}$$

$$z_I = 0.1\ C_R \tan(22.5 - 0.5\alpha) \quad \text{for} \quad \alpha \leq 15^\circ \tag{6.c}$$

or $$z_I = 0.1\ C_R \tan\alpha \qquad \text{for} \quad \alpha \geq 15^\circ \tag{6.d}$$

where C_R is the root chord and α is the angle of attack. Initially point J is one root chord away from the trailing-edge. The segments between point I and J are of equal length and lie in a plane parallel to x-z plane. These segments are approximately at a height of $0.1 \cdot C_R$ above the wing plane. In the final converged position all the segments between points H and J are aligned in the direction of the local velocity vector.

d. The semi-infinite segments from points A to infinity and J to infinity are straight and are parallel to the undisturbed free-stream direction.

2.4 SOLUTION PROCEDURE

The basic unknowns of the problem are the bound vortex density on the wing, and the strengths and the locations of the elements of the leading-edge vortex system and the wake. The problem is nonlinear because the locations of the leading-edge vortex system and the wake are unknown a priori. Therefore, the problem is solved by the iterative process described below;

a. Prescribe the vortex lattice for the wing surface, and the initial locations of the free elements over the wing and in the wake.

b. By satisfying the wing boundary condition, obtain the bound vortex density of the wing and the strengths of free elements.

c. Calculate all the aerodynamic characteristics.

d. Calculate the forces acting on the free elements over the wing surface.

e. Adjust the free elements of the leading-edge vortex system and the wake in the local velocity vector direction.

f. Repeat steps b through e until a converged solution is obtained.

The initial locations of the free vortex elements are assumed by letting them leave the leading-edge in the undisturbed free-stream direction up-to a height of about ten percent of the root chord beyond which the elements are parallel to the wing plane. Initially, all the elements of the wake lie in the plane of the wing. In the iteration process, the force free condition is satisfied on the free elements from the root to the tip in the down-stream direction. The elements over the wing are adjusted before the elements of the wake. In the first iteration the segments over the wing are moved 100 percent according to the velocity computed at their mid-points. This movement is gradually reduced in steps of 90, 80 and 75 percent in the next three iterations, after which it remains at 75 percent (Section 2.5.2 of ref. 1). The segments in the wake are moved only 50 percent in each iteration. Thus, exact force free condition is not enforced because whenever the free elements come close to each other they induce unreasonably large velocities because viscous effects are not included in the present theory. These large velocities increase the forces on the segments and induce fluctuations in their locations.

The solution is assumed to have converged if in two consecutive iterations the difference between the total strengths of leading-edge free vortex elements is less than one percent and the absolute force acting on the free elements is in the neighborhood of a minimum. Thus, an exact force free condition is not enforced as discussed in the previous paragraph.

3. INPUT DATA FORMAT

The following is the description of input data cards for this program.

Card 1. Format (16A5)

TTL — Any title identifying the case to be run. END in first three columns terminates the job.

Card 2. Format (6I5)

NCW — Number of chordwise lines (limited to nine)

NSW — Number of spanwise lines (one higher than number of spanwise strips of panels, limited to twenty). It depends on aspect-ratio and is determined by using figure 2.

NBRR — Number of constant x-locations where ΔC_p's are to be interpolated (limited to twenty-five).

NCONTS — = 0, Initial locations of free elements will be calculated in the program.

= 1, Initial locations of free elements will be read from data cards.

MITER — Maximum number of iterations to be performed (usually between 10 and 15)

IPUNCH — = 0, Coordinates of free elements will not be punched out after last iteration.

= 1, Coordinates of free elements will be punched out after last iteration.

Card 3. Format (6F10.5)

XXL(1) — Leading-edge x-coordinate of the root chord.

XXT(1)	Trailing-edge x-coordinate of the root chord.
YL(1)	y-coordinate of the root chord
XXL(2)	Leading-edge x-coordinate of the tip chord.
XXT(2)	Trailing-edge x-coordinate of the tip chord.
YL(2)	y-coordinate of the tip chord.

Card 4. Format (7F10.5)

ALPHA	Angle of attack (in degrees).
AMACH	Mach number.
DELTA	Length of a segment of leading-edge free vortex elements (may be taken as 0.15 C_R).
DL	Length of a segment of wake elements (may be taken as 0.15 C_R).
XEND	x-coordinate beyond which free elements of leading-edge and wake system are represented by a single element going to infinity.
CBAR	Reference chord.
AREA	Total reference wing area.

Card 5. Format (8F10.5)

XBRR(I), I = 1, NBRR	Constant x-locations where ΔC_p's are to interpolated.

Card 6. Format (8F10.5)

CTT(I), I = 1,(NSW-1)	Sectional leading-edge thrust coefficients for spanwise strips. All these values are set equal to zero for complete leading-edge separation.

*** If NCONTS = 0, go back to card number 1 ***

Card 7. Format (10I2)

NELM(I), One higher than the number of segments for each leading-
I = 1,(NSW-1) edge free vortex element (numbered from root to tip).

Card 8. Format (8F10.5)

XE(K) x-coordinates of the end-points of segments of Ith
K = 1,NELM(I) leading-edge free vortex element.

Card 9. Format (8F10.5)

YE(K), y-coordinates of the end-points of segments of Ith
K = 1,NELM(I) leading-edge free vortex element.

Card 10. Format (8F10.5)

ZE(K) z-coordinates of the end-points of segments of Ith
K = 1,NELM(I) leading-edge free vortex element.

Cards 8 thru 10 are repeated (NSW-1) times.

Card 11. Format (10I2)

NNELM(I), One higher than the number of segments for each wake
I = 1,NSW element (numbered from root to tip).

Card 12. Format (8F10.5)

XXE(K) x-coordinates of the end-points of segments of Ith
K = 1,NNELM(I) trailing wake element.

Card 13. Format (8F10.5)

YYE(K) y-coordinates of the end-points of segments of Ith
K = 1,NNELM(I) trailing wake element.

Card 14. Format (8F10.5)

ZZE(K), z-coordinates of the end-points of segments of Ith
K = 1,NNEM(I) trailing wake element.

*** Cards 12 thru 14 are repeated NSW times.***

*** Go back to card number 1.***

Note: The punched data cards obtained by running this program with IPUNCH = 1, can be directly used for cards 7 thru 14 for further iterations.

4. OUTPUT DATA FORMAT

All the input data cards for each case are listed at the beginning of the output. The output data at each iteration step is as follows:

The title card (input data card number 1) is printed-out as it is inputted. The angle-of-attack (in degrees), Mach Number and iteration number are also listed. The end-point locations of the leading-edge free elements are listed next. The first row of numbers in each group are the x-coordinates, second row the y-coordinates and third row the z-coordinates. The end-point locations of the wake elements are listed in the similar manner. On the next two pages, x-y and y-z digital plots for leading-edge free-elements are made. It is to be noted that the leading-edge elements lying in the plane of the wing and along center line are not plotted. So, the elements next to the center line are represented by "1". When similar numbers are connected by straight lines, they represent the path of a free vortex element. A "+" sign represents a duplicate point. In these two plots there are (NSW-2) rows of free elements. The digital plots for wake elements are made on next two pages. The elements along center line are again not plotted. There are (NSW-1) elements.

Some of the intermediate variables are listed under following labels:

X/C	Percent chord location
2Y/B	Percent span location
GAMAY	Bound vortex density over the wing (γ_y) at the given (X/C, 2Y/B)
CAPGAMA	Strength of leading-edge free element (Γ) at the given 2Y/B
DELTA-CP	The total ΔC_p at the given (X/C, 2Y/B)

The sectional properties are listed under the following labels:

I	Spanwise station number (numbered from root to tip)
CLI	The sectional lift coefficient
CMI	The sectional pitching moment coefficient about the y-axis
CDI	The sectional induced drag coefficient
CTI	The sectional leading-edge thrust coefficient.

The total lift, pitching moment, induced drag and leading-edge thrust coefficients are listed after sectional properties. The spanwise pressures at constant x-locations are listed under following labels:

Y	y-coordinate
2Y/B(LOCAL)	Percent span location based on local span
DELTA-CP	The total ΔC_p at the given (x,y)

The last item listed for each iteration is the absolute force acting on leading-edge free elements.

The last page of the output is the "Summary Sheet", which is used to pick up final converged solution. It has the following format:

The title (input data card number 1) is printed again. The angle of attack (in degrees) and Mach Number are also listed. The other variables listed are,

ITERATION	Iteration number
CL	The total lift coefficient
CM	The total pitching moment coefficient about y-axis
CD	The total induced drag coefficient
CT	The total leading-edge thrust coefficient
GMSUM	Total sum of the strengths of leading-edge free vortex elements, except the one at the center line.

PERR	Percent change in GMSUM values of two consecutive iterations
TFABS	Total absolute force acting on leading-edge free elements

This program has not yet been completely automated and the converged solution is to be picked by the user, from the Summary Sheet, by using the following criteria:

The solution is assumed to have converged if in two consecutive iterations the difference between the total strengths of leading-edge free vortex elements is less than one percent and the absolute force acting on the free elements is in the neighborhood of a minimum.

5. REFERENCES

1. Mehrotra, S. C. and Lan, C. E., "A Theoretical Investigation of the Aerodynamics of Low-Aspect-Ratio Wings with Partial Leading-Edge Separation", NASA CR-145304, January 1978.
2. Lan, C. E., "A Quasi-Vortex-Lattice Method in Thin Wing Theory", Journal of Aircraft, Vol. 11, No. 9, pp. 518-527, Sept. 1974.
3. Lamar, J. E. and Gloss, B. B., "Subsonic Aerodynamic Characteristics of Interacting Lifting Surfaces with Separated Flows around Sharp Edges Predicted by a Vortex Lattice Method", NASA TN D-7921, Sept. 1975.

6. APPENDICES

6.1 APPENDIX A: EXAMPLE INPUT AND OUTPUT

The following is an example of delta wing of aspect-ratio 2 at an angle-of-attack of 30 degrees. The flow is assumed to be completely separated from the leading-edge and so sectional leading-edge thrust coefficients are set to zero on card number 6. Listing of input data cards is given below:

<u>Listing of Input Data Cards</u>

```
                                               C O L U M N   N U M B E R
                         11111111112222222222333333333344444444445555555555666666666677777777778
                12345678901234567890123456789012345678901234567890123456789012345678901234567890
CARD NUMBER
     1                                    ASPECT RATIO = 2.0
     2                 6       7       5       0   10      0
     3          0.             4.             0.             4.             4.             2.
     4          30.            0.             0.6            0.6            7.5            2.             8.
     5          1.             2.             3.             3.5            3.75
     6          0.             0.             0.             0.             0.             0.
     7          END
```

Output data is listed on the following pages. An inspection of the "Summary Sheet" suggests that the converged solution has been reached at 8th iteration.

```
INPUT DATA CARDS
                    ASPECT RATIO = 2.0
   6    7    5    0   10    0
  0.00000   4.00000   0.00000   4.00000   4.00000   2.00000
 30.00000   0.00000    .60000    .60000   7.50000   2.00000   8.00000
  1.00000   2.00000   3.00000   3.50000   3.75000
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
END OF INPUT DATA
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
                    ASPECT RATIO = 2.0
ALPHA(DEG.)=30.000  MACH NUMBER= 0.000  ITERATION NUMBER= 0

LEADING EDGE ELEMENTS
*********************
**** 1****
  4.0000   .4810   .0501  0.0000  -.2000   .2000   .7196
   .2182   .2182  0.0300  0.0000  0.0000  0.0000  0.0000
  0.0000  0.0000  0.0000  0.0000  0.0000   .2309   .5309
**** 2****
  4.0000  1.1682   .4810   .4353   .2582   .6145  1.1341  1.7341  2.3341  2.9341  3.5341  4.1341  4.7341  5.3341
  5.9341  6.5341  7.1341  7.7341
   .5661   .5661   .2182   .2182   .2182   .2182   .2182   .2182   .2182   .2182   .2182   .2182   .2182   .2182
   .2182   .2182   .2182   .2182
  0.0000  0.0000  0.0000  0.0000  0.0000   .2309   .5309   .5309   .5309   .5309   .5309   .5309   .5309   .5309
   .5309   .5309   .5309   .5309
**** 3****
  4.0000  2.0251  1.1682  1.1322   .9388  1.2756  1.7952  2.3952  2.9952  3.5952  4.1952  4.7952  5.3952  5.9952
  6.5952  7.1952  7.7952
  1.0000  1.0000   .5661   .5661   .5661   .5661   .5661   .5661   .5661   .5661   .5661   .5661   .5661   .5661
   .5661   .5661   .5661
  0.0000  0.0000  0.0000  0.0000  0.0000   .2309   .5309   .5309   .5309   .5309   .5309   .5309   .5309   .5309
   .5309   .5309   .5309
**** 4****
  4.0000  2.9820  2.0251  2.0000  1.9000  2.1000  2.6196  3.2196  3.8196  4.4196  5.0196  5.6196  6.2196  6.8196
  7.4196  8.0196
  1.4339  1.4339  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000  1.0000
  1.0000  1.0000
  0.0000  0.0000  0.0000  0.0000  0.0000   .2309   .5309   .5309   .5309   .5309   .5309   .5309   .5309   .5309
   .5309   .5309
**** 5****
  4.0000  3.5691  2.8320  2.8578  2.8112  2.9244  3.4440  4.0440  4.6440  5.2440  5.8440  6.4440  7.0440  7.6440
  1.7814  1.7819  1.4339  1.4339  1.4339  1.4339  1.4339  1.4339  1.4339  1.4339  1.4339  1.4339  1.4339  1.4339
  0.0000  0.0000  0.0000  0.0000  0.0000   .2309   .5309   .5309   .5309   .5309   .5309   .5309   .5309   .5309
**** 6****
  4.0000  3.9505  3.5691  3.5537  3.5418  3.5855  4.1051  4.7051  5.3051  5.9051  6.5051  7.1051  7.7051
  1.9749  1.9749  1.7818  1.7818  1.7818  1.7818  1.7818  1.7818  1.7818  1.7818  1.7818  1.7818  1.7818
  0.0000  0.0000  0.0000  0.0000  0.0000   .2309   .5309   .5309   .5309   .5309   .5309   .5309   .5309
```

```
WAKE ELEMENTS
*************
**** 1****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 2****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
   .2182     .2182     .2182     .2182     .2182     .2182     .2182     .2182
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 3****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
   .5661     .5661     .5661     .5661     .5661     .5661     .5661     .5661
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 4****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
  1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000    1.0000
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 5****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
  1.4339    1.4339    1.4339    1.4339    1.4339    1.4339    1.4339    1.4339
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 6****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
  1.7818    1.7818    1.7818    1.7818    1.7818    1.7818    1.7818    1.7818
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
**** 7****
  4.0000    4.4000    4.8000    5.4000    6.0000    6.6000    7.2000    7.8000
  1.9749    1.9749    1.9749    1.9749    1.9749    1.9749    1.9749    1.9749
  0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
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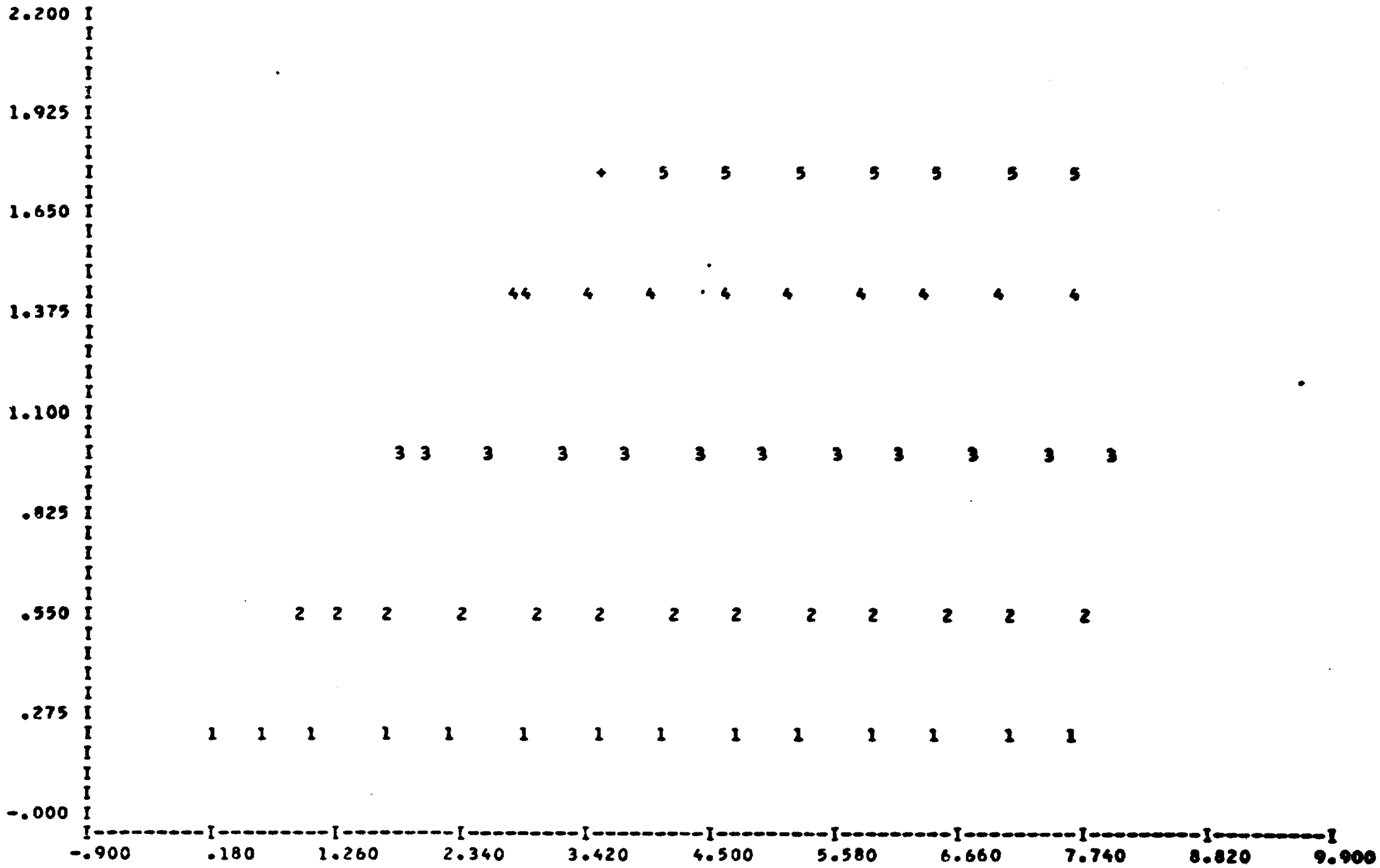
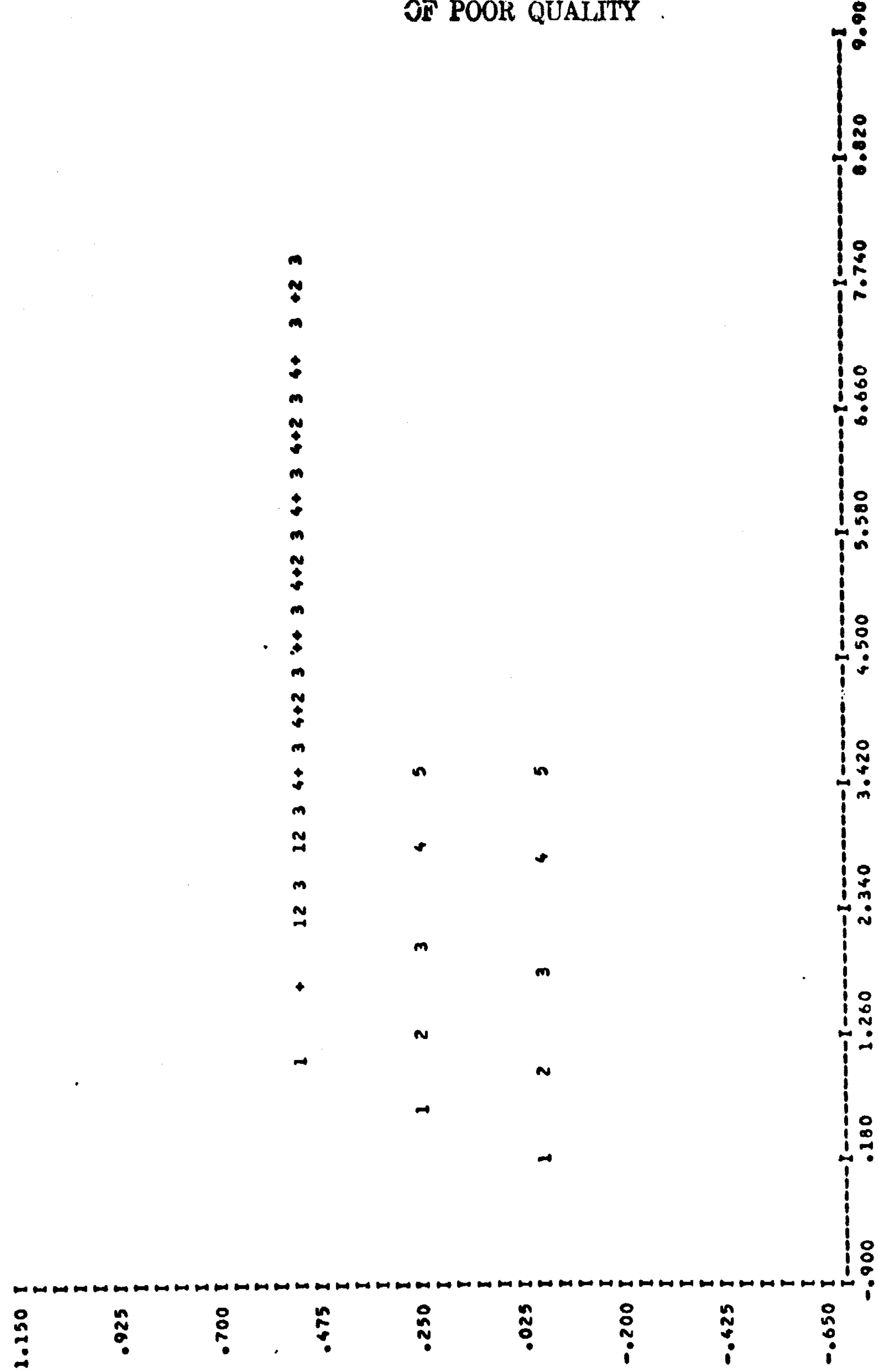
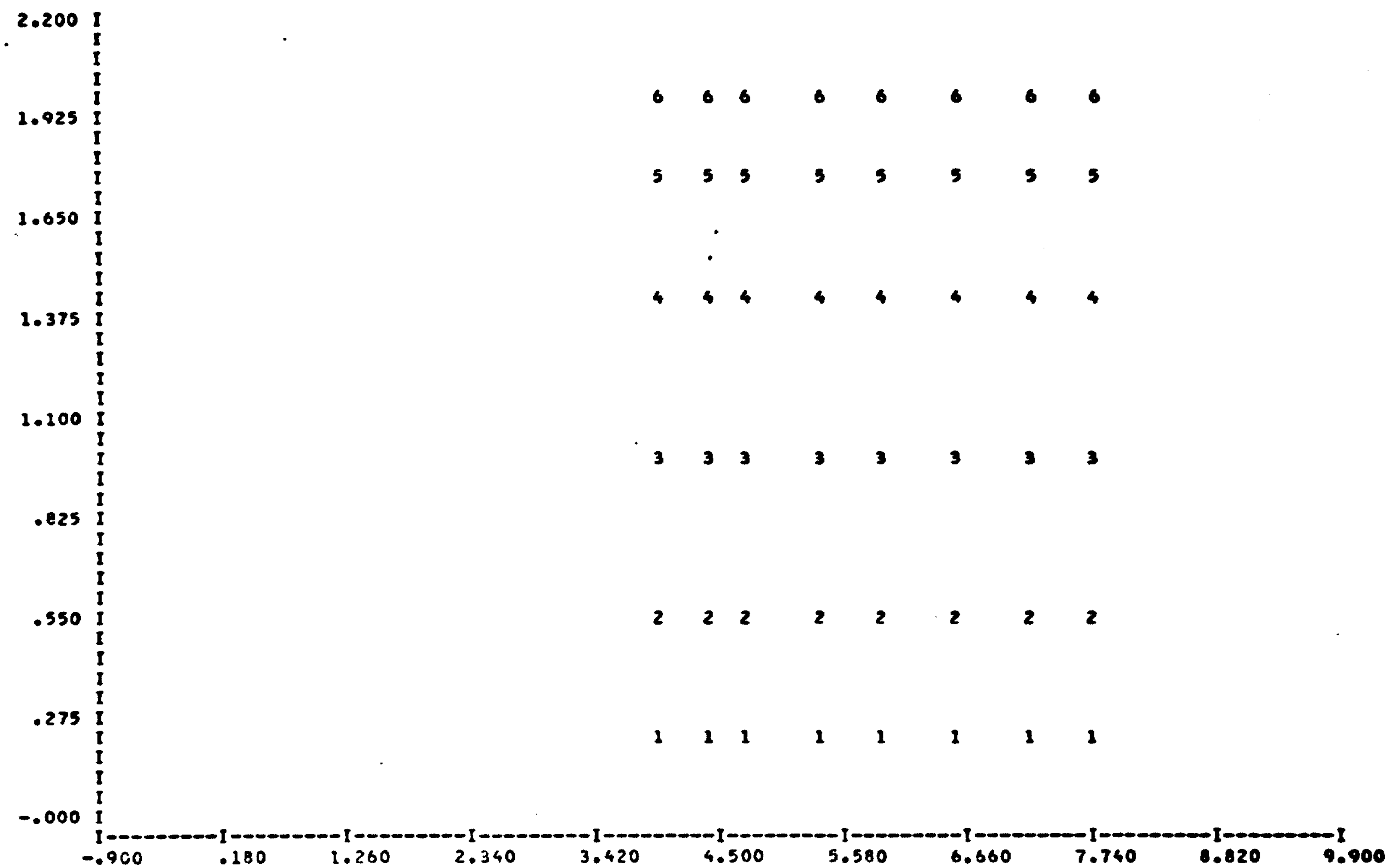


X VS Y(LEADING-EDGE ELEMENTS)

ORIGINAL PAGE IS
OF POOR QUALITY



X VS Z(LEADING-EDGE ELEMENTS)



X VS Y(WAKE ELEMENTS)

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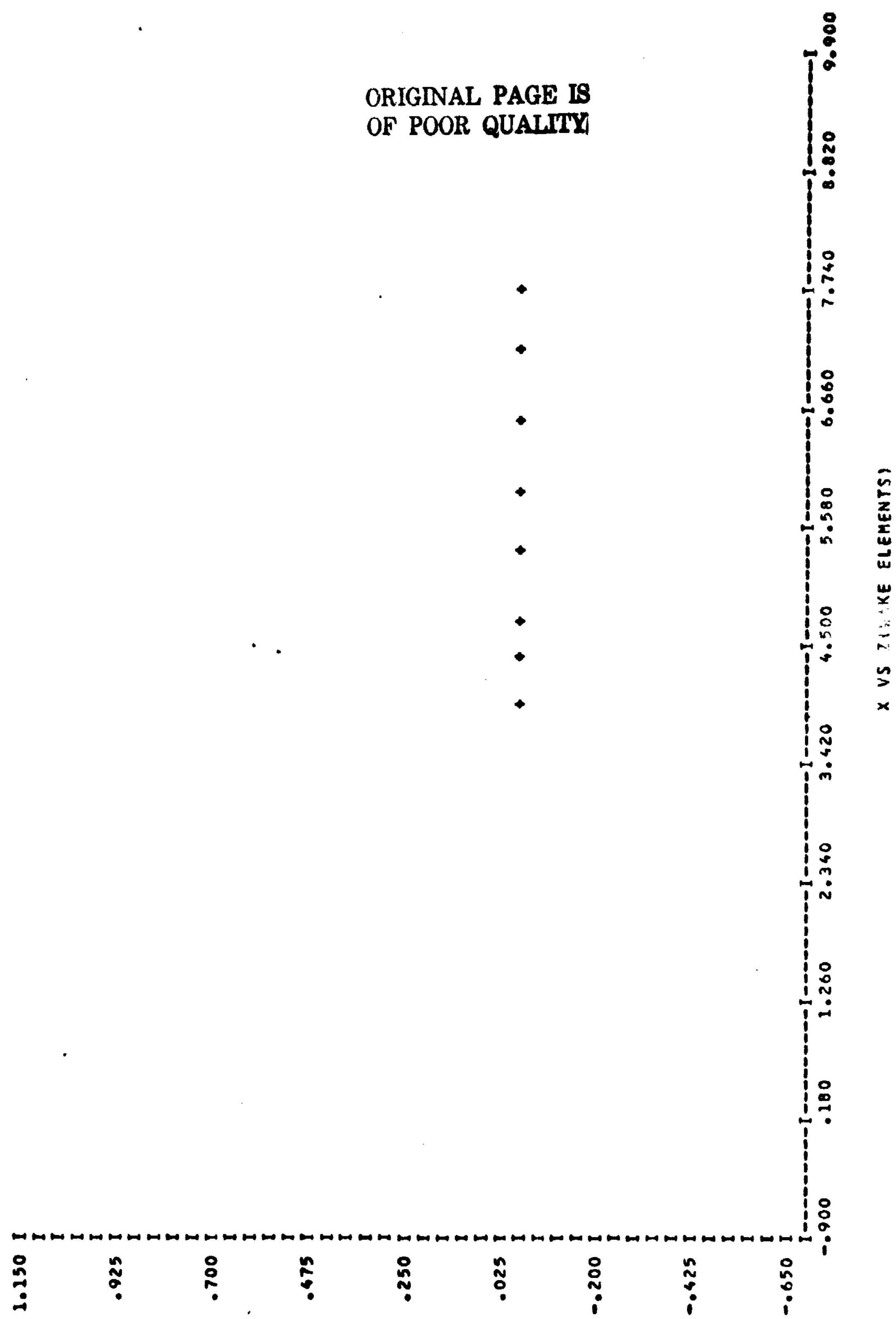
OF POOR QUALITY



WING VORTEX STRENGTHS
****

X/C	2Y/B	GAMAY
***	****	*****
.01704	.04952	8.33720
.14645	.04952	1.56297
.37059	.04952	.80264
.62941	.04952	.44407
.85355	.04952	.22943
.98296	.04952	.07193
.01704	.18826	5.99420
.14645	.18826	1.18337
.37059	.18826	.73233
.62941	.18826	.44816
.85355	.18826	.23360
.98296	.18826	.07046
.01704	.38874	6.94864
.14645	.38874	1.00875
.37059	.38874	.71030
.62941	.38874	.44483
.85355	.38874	.23903
.98296	.38874	.07714
.01704	.61126	8.69819
.14645	.61126	1.01388
.37059	.61126	.75967
.62941	.61126	.47910
.85355	.61126	.25817
.98296	.61126	.07882
.01704	.81174	11.59210
.14645	.81174	1.22090
.37059	.81174	.82058
.62941	.81174	.56037
.85355	.81174	.30312
.98296	.81174	.09232
.01704	.95048	17.69230
.14645	.95048	1.80028
.37059	.95048	1.10401
.62941	.95048	.77418
.85355	.95048	.44792
.98296	.95048	.13807

LEADING-EDGE VORTICES STRENGTHS
****

2Y/B   CAPGAMA

****	*******
.04952	1.59529
.18826	1.00437
.38874	.89376
.61126	.71560
.81174	.46288
.95048	.18600

DELTA-CP DISTRIBUTION
****

X/C ***	2Y/B ****	DELTA-CP ********
.01254	.04952	10.99014
.10908	.04952	5.20072
.28306	.04952	1.89953
.50000	.04952	1.53386
.71694	.04952	.63537
.89092	.04952	.60226
.98746	.04952	.19361
.01254	.18826	10.23401
.10908	.18826	3.02399
.28306	.18826	1.66076
.50000	.18826	1.48151
.71694	.18826	1.05696
.89092	.18826	.88171
.98746	.18826	.53502
.01254	.38874	5.78581
.10908	.38874	3.46117
.28306	.38874	1.78347
.50000	.38874	1.32014
.71694	.38874	1.35983
.89092	.38874	.93750
.98746	.38874	.90278
.01254	.61126	4.22909
.10908	.61126	2.96873
.28306	.61126	1.38105
.50000	.61126	.92197
.71694	.61126	.95365
.89092	.61126	.59231
.98746	.61126	.44996
.01254	.81174	3.41732
.10908	.81174	2.72773
.28306	.81174	1.32286
.50000	.81174	.79997
.71694	.81174	.50924
.89092	.81174	.25959
.98746	.81174	-.08718
.01254	.95048	2.86271
.10908	.95048	2.70303
.28306	.95048	1.17791
.50000	.95048	.82040
.71694	.95048	.18540
.89092	.95048	-.14688
.98746	.95048	-.76388

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SECTIONAL PROPERTIES
****

I	CLI	CMI	CDI	CTI
*	***	***	***	***
1	1.92867	-1.25424	1.11352	0.00000
2	1.70269	-1.71973	.98305	0.00000
3	1.62912	-2.27566	.94057	0.00000
4	1.22177	-2.08599	.70539	0.00000
5	.98222	-1.95844	.56708	0.00000
6	.79862	-1.77018	.46108	0.00000

TOTAL LIFT COEFFICIENT= 1.55805
TOTAL PITCHING MOMENT COEFFICIENT= -1.83185
TOTAL DRAG COEFFICIENT= .89954
TOTAL THRUST COEFFICIENT= 0.00000

SPANWISE PRESSURES AT CONSTANT X= 1.00000

Y	2Y/B(LOCAL)	DELTA-CP
.09903	.19806	2.73389
.37651	.75302	3.83013

SPANWISE PRESSURES AT CONSTANT X= 2.00000

Y	2Y/B(LOCAL)	DELTA-CP
.09903	.09903	1.55729
.37651	.37651	1.55829
.77748	.77748	2.62486

SPANWISE PRESSURES AT CONSTANT X= 3.00000

Y	2Y/B(LOCAL)	DELTA-CP
.09903	.06602	.54461
.37651	.25101	1.11094
.77748	.51832	1.37594
1.22252	.81501	1.05633

SPANWISE PRESSURES AT CONSTANT X= 3.50000

Y	2Y/B(LOCAL)	DELTA-CP
.09903	.05659	.50101
.37651	.21515	.8919[illegible]
.77748	.44427	1.223[illegible]
1.22252	.69858	.98009
1.623[illegible]	.92771	1.[illegible]

```
SPANWISE PRESSURES AT CONSTANT X=    3.75000
       Y      2Y/B(LOCAL) DELTA-CP
     .09903     .05282      .79304
     .37651     .20081      .86444
     .77748     .41466      .91482
    1.22252     .65201      .73136
    1.62349     .86586      .59463

TOTAL ABSOLUTE FORCE ACTING ON LEADING-EDGE FREE ELEMENTS=    1.28618
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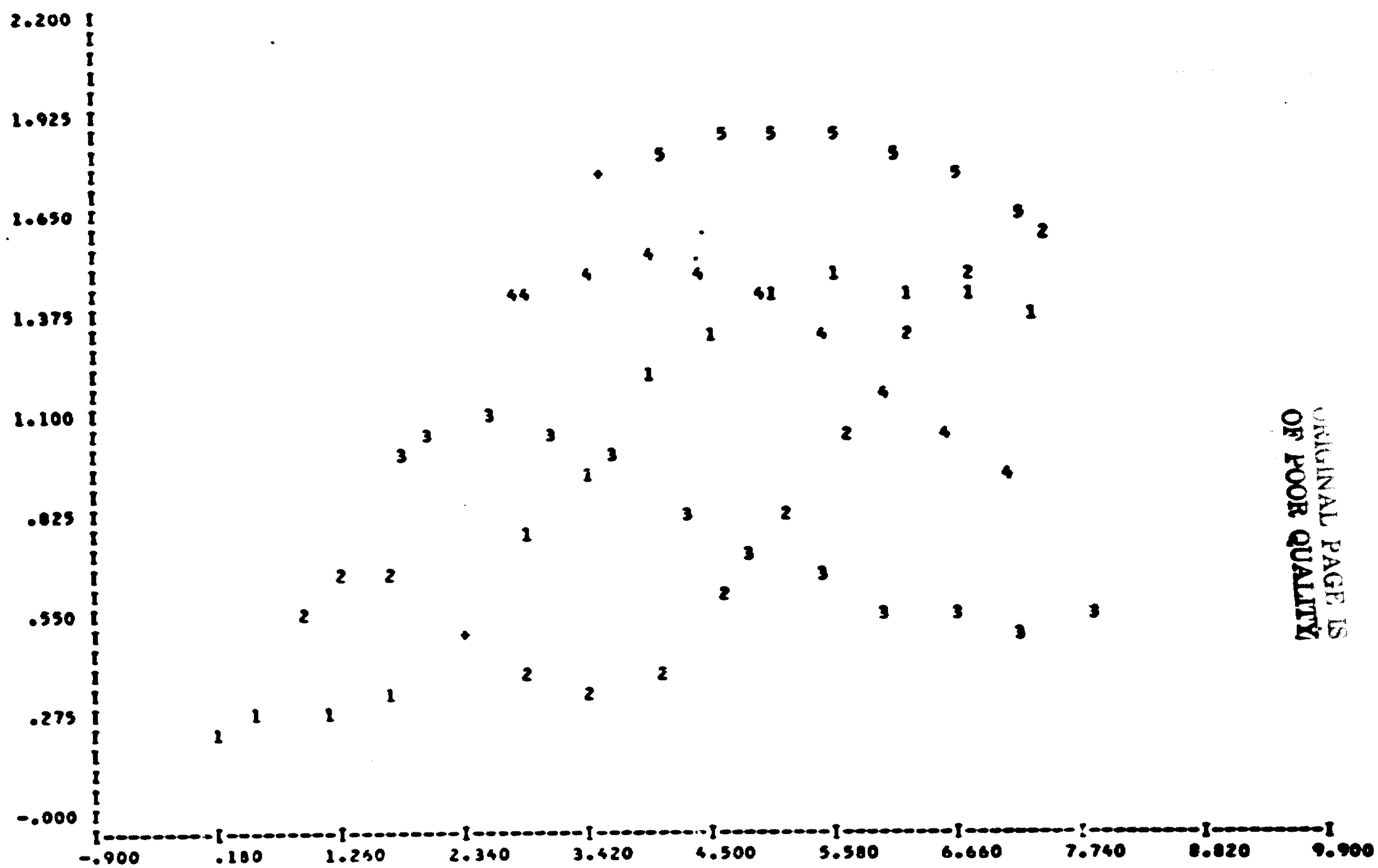
                    ASPECT RATIO = 2.0
ALPHA(DEG.)=30.000  MACH NUMBER= 0.000  ITERATION NUMBER= 1

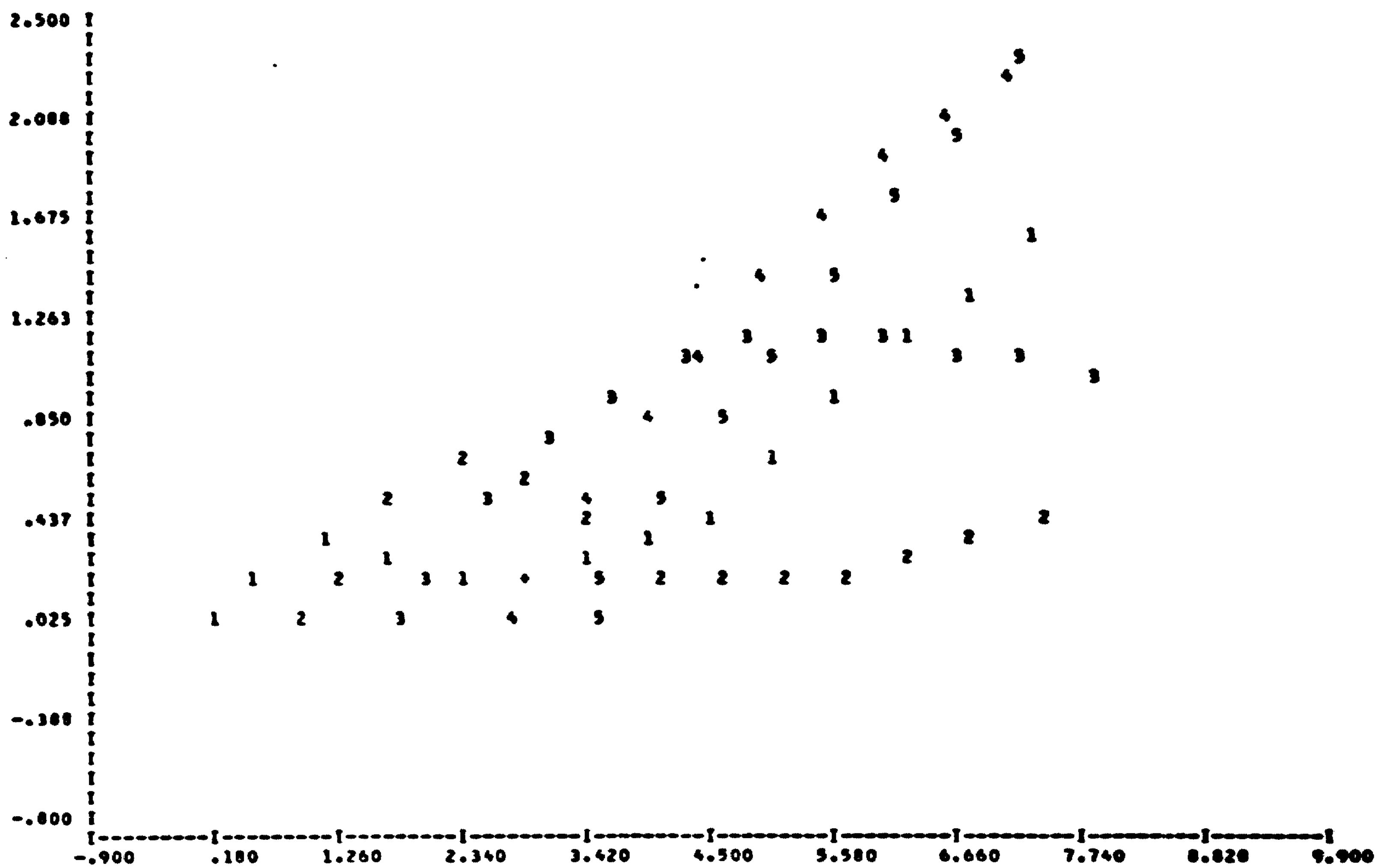
LEADING EDGE ELEMENTS
********************
**** 1*****
  4.0000    .4810    .0501   0.0000   -.2000    .2000    .7196
   .2182    .2182   0.0000   0.0000   0.0000   0.0000   0.0000
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5309
**** 2*****
  4.0000   1.1682    .4810    .4363    .2562    .6067   1.1952   1.7829   2.3561   2.9027   3.4649   4.0129   4.5776   5.1348
  5.6827   6.2333   6.7860   7.3369
   .5661    .5661    .2182    .2182    .2182    .2926    .2742    .3201    .4976    .7449    .9539   1.1836   1.3443   1.4359
  1.4581   1.4401   1.4047   1.3561
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .3463    .2349    .2309    .2309    .2488    .3321    .4558    .6586
   .9021   1.1398   1.3705   1.6032
**** 3*****
  4.0000   2.0251   1.1682   1.1322    .9888   1.2612   1.7944   2.3666   2.9451   3.5112   4.0768   4.6509   5.2020   5.7484
  6.2891   6.8571   7.4311
  1.0000   1.0000    .5661    .5661    .5661    .6558    .6364    .5219    .3673    .3268    .4114    .5858    .8231   1.0709
  1.3310   1.5069   1.6063
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5054    .6450    .6069    .4122    .2309    .2309    .2309    .2309
   .2402    .3201    .4636
**** 4*****
  4.0000   2.8820   2.0251   2.0000   1.9000   2.0917   2.6107   3.1595   3.7208   4.2938   4.8801   5.4734   6.0696   6.6667
  7.2642   7.8624
  1.4339   1.4339   1.0000   1.0000   1.0000   1.0570   1.0825   1.0573    .9651    .8359    .7247    .6371    .5714    .5284
   .5127    .5381
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5309    .7722    .9629   1.0855   1.1476   1.1665   1.1515   1.1108
  1.0585   1.0192
**** 5*****
  4.0000   3.5691   2.8820   2.8578   2.8112   2.9228   3.4416   3.9669   4.4859   5.0027   5.5286   6.0679   6.6213   7.1861
  1.7818   1.7818   1.4339   1.4339   1.4339   1.4528   1.4817   1.5146   1.4893   1.4114   1.3013   1.1750   1.0484    .9276
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5309    .8190   1.1190   1.4137   1.6808   1.9114   2.1057   2.2681
**** 6*****
  4.0000   3.9505   3.5691   3.5637   3.5418   3.5651   4.1043   4.6211   5.1400   5.6595   6.1774   6.6921   7.2028
  1.9749   1.9749   1.7818   1.7818   1.7818   1.7761   1.7972   1.8516   1.8787   1.8686   1.8269   1.7553   1.6596
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5309    .8309   1.1309   1.4309   1.7309   2.0309   2.3309
```

WAKE ELEMENTS
****

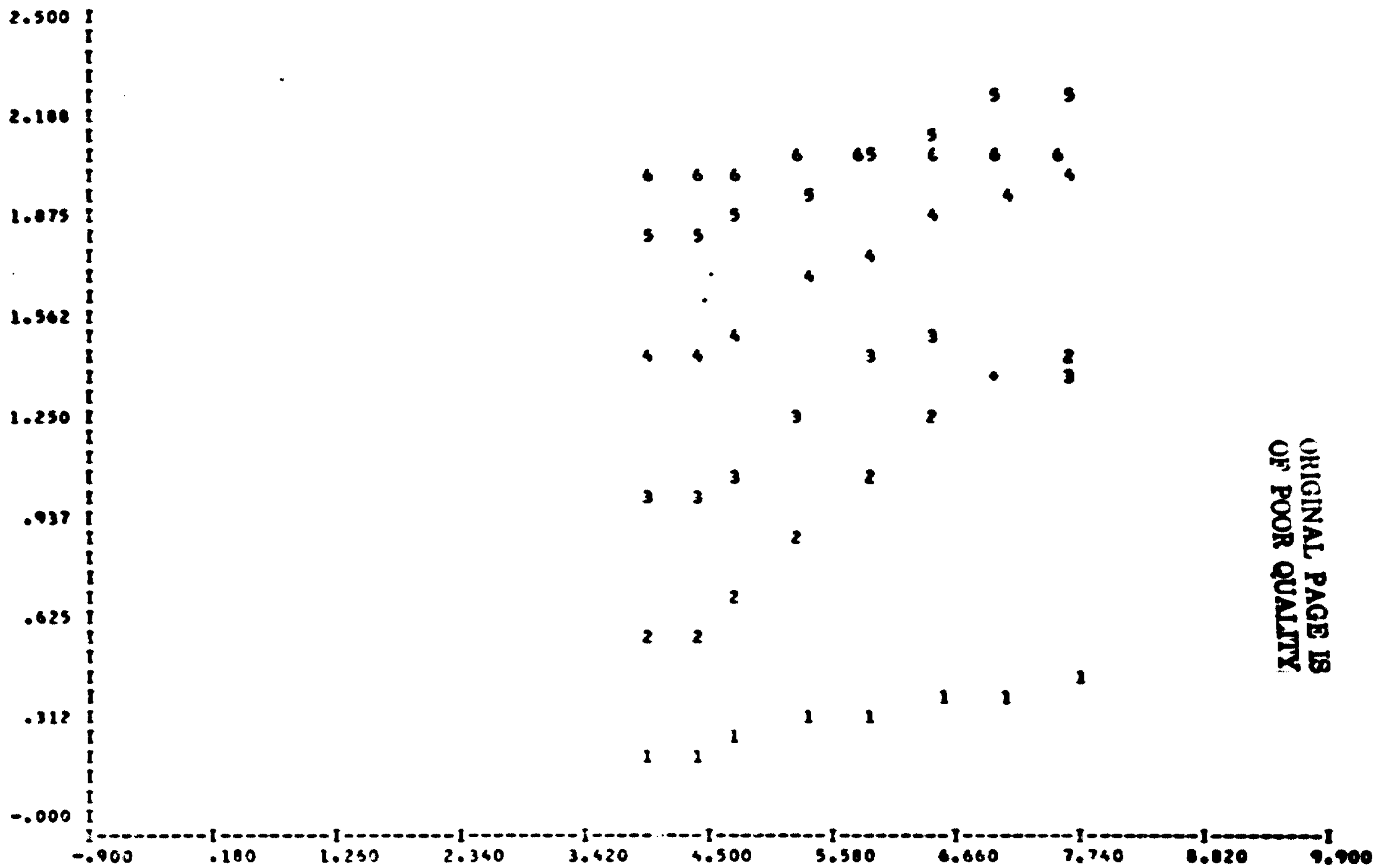
**** 1****							
4.0000	4.4000	4.8000	5.4000	6.0000	6.6000	7.2000	7.8000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
**** 2****							
4.0000	4.4000	4.7969	5.3953	5.9940	6.5920	7.1890	7.7847
.2182	.2182	.2578	.3015	.3359	.3660	.3956	.4263
0.0000	0.0000	-.0295	-.0380	-.0191	.0188	.0711	.1362
**** 3****							
4.0000	4.4000	4.7766	5.3421	5.9134	6.4944	7.0814	7.6696
.5661	.5661	.7009	.9010	1.0842	1.2337	1.3542	1.4563
0.0000	0.0000	-.0047	-.0174	-.0124	-.0047	.0257	.0859
**** 4****							
4.0000	4.4000	4.7883	5.3637	5.9220	6.4620	7.0440	7.6423
1.0000	1.0000	1.0935	1.2481	1.4221	1.5050	1.3919	1.3901
0.0000	0.0000	.0225	.0931	.2274	.4753	.5674	.5224
**** 5****							
4.0000	4.4000	4.7857	5.3673	5.9494	6.5284	7.1000	7.6664
1.4339	1.4339	1.5302	1.6578	1.7672	1.8530	1.9251	1.9971
0.0000	0.0000	.0440	.1184	.2137	.3459	.5135	.6979
**** 6****							
4.0000	4.4000	4.7877	5.3675	5.9425	6.5136	7.0814	7.6465
1.7918	1.7918	1.8458	1.9524	2.0615	2.1512	2.2193	2.2745
0.0000	0.0000	.0750	.1866	.3185	.4793	.6607	.8548
**** 7****							
4.0000	4.4000	4.7740	5.3314	5.8961	6.4717	7.0506	7.6294
1.9749	1.9749	2.0235	2.0791	2.0785	2.0702	2.0623	2.0566
0.0000	0.0000	.1334	.3483	.5509	.7203	.8778	1.0359



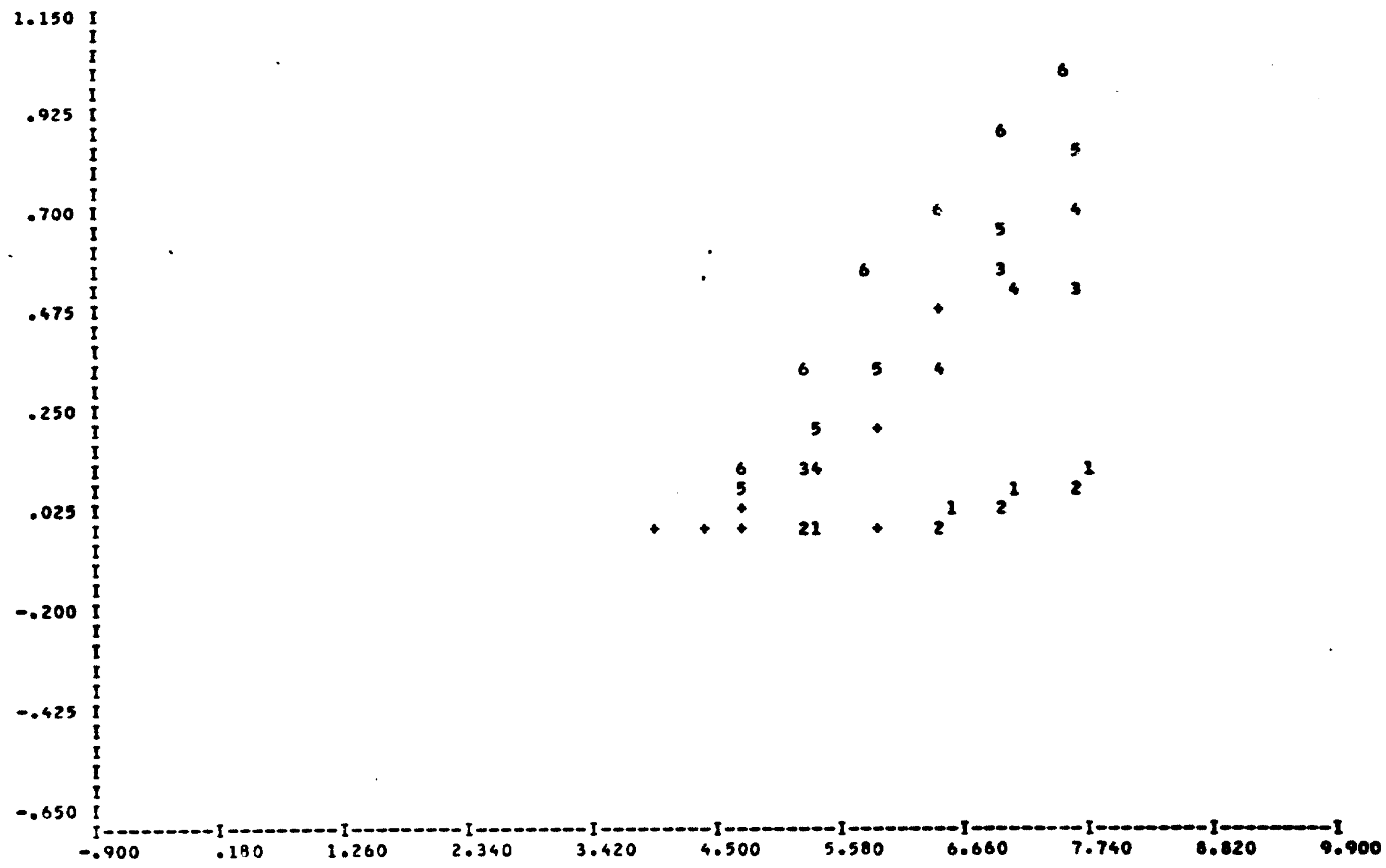
X VS Y(LEADING-EDGE ELEMENTS)



X VS Z(LEADING-EDGE ELEMENTS)



X VS Y(WAKE ELEMENTS)



X VS Z(WAKE ELEMENTS)

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WING VORTEX STRENGTHS
****

X/C ***	2Y/B ****	GAMAY *****
.01704	.04952	8.25052
.14645	.04952	1.36927
.37059	.04952	.61192
.62941	.04952	.51188
.85355	.04952	.22160
.98296	.04952	.03334
.01704	.18826	5.80367
.14645	.18826	1.10192
.37059	.18826	.47379
.62941	.18826	.46969
.85355	.18826	.29190
.98296	.18826	.03814
.01704	.38874	7.13406
.14645	.38874	1.02614
.37059	.38874	.61492
.62941	.38874	.11650
.85355	.38874	.30132
.98296	.38874	.13724
.01704	.61126	8.92539
.14645	.61126	1.04178
.37059	.61126	.75280
.62941	.61126	.40170
.85355	.61126	.08733
.98296	.61126	-.00273
.01704	.81174	11.70835
.14645	.81174	1.22415
.37059	.81174	.80887
.62941	.81174	.53281
.85355	.81174	.27362
.98296	.81174	.08046
.01704	.95048	17.57687
.14645	.95048	1.78459
.37059	.95048	1.09015
.62941	.95048	.76081
.85355	.95048	.43806
.98296	.95048	.13460

LEADING-EDGE VORTICES STRENGTHS
****

2Y/B C [illegible]GAMA

****	*******
.04952	1.58978
.18826	.96851
.38874	.91597
.61126	.73407
.81174	.46763
.95048	.18480

DELTA-CP DISTRIBUTION
****

X/C ***	2Y/B ****	DELTA-CP ********
.01254	.04952	9.56653
.10908	.04952	4.96700
.28306	.04952	1.65211
.50000	.04952	1.42061
.71694	.04952	.79068
.89092	.04952	.52909
.98746	.04952	.24339
.01254	.18826	8.81633
.10908	.18826	2.68645
.28306	.18826	1.96220
.50000	.18826	1.82361
.71694	.18826	1.35237
.89092	.18826	.90122
.98746	.18826	.65134
.01254	.38874	5.57613
.10908	.38874	3.48906
.28306	.38874	2.25933
.50000	.38874	1.84106
.71694	.38874	1.93991
.89092	.38874	1.54343
.98746	.38874	1.23947
.01254	.61126	4.02855
.10908	.61126	2.83133
.28306	.61126	1.32986
.50000	.61126	1.00104
.71694	.61126	1.23559
.89092	.61126	.90902
.98746	.61126	.97263
.01254	.81174	3.29553
.10908	.81174	2.57849
.28306	.81174	1.22989
.50000	.81174	.66425
.71694	.81174	.38255
.89092	.81174	.14927
.98746	.81174	-.14288
.01254	.95048	2.58105
.10908	.95048	2.40211
.28306	.95048	1.07138
.50000	.95048	.69590
.71694	.95048	.11024
.89092	.95048	-.21056
.9874[illegible]	.950[illegible]	-.78007

SECTIONAL PROPERTIES
****

I	CLI	CMI	CDI	CTI
*	***	***	***	***
1	1.79394	-1.20941	1.03573	0.00000
2	1.77886	-1.91614	1.02703	0.00000
3	1.99753	-2.92693	1.15327	0.00000
4	1.31320	-2.30045	.75818	0.00000
5	.87826	-1.74180	.50706	0.00000
6	.68555	-1.51759	.39580	0.00000

TOTAL LIFT COEFFICIENT= 1.66094
TOTAL PITCHING MOMENT COEFFICIENT= -2.07341
TOTAL DRAG COEFFICIENT= .95894
TOTAL THRUST COEFFICIENT= 0.00000

SPANWISE PRESSURES AT CONSTANT X= 1.00000

Y	2Y/B(LOCAL)	DELTA-CP
.09903	.19806	2.52115
.37651	.75302	3.26689

SPANWISE PRESSURES AT CONSTANT X= 2.00000

Y	2Y/B(LOCAL)	DELTA-CP
.09903	.09903	1.40684
.37651	.37651	1.92070
.77748	.77748	2.89741

SPANWISE PRESSURES AT CONSTANT X= 3.00000

Y	2Y/B(LOCAL)	DELTA-CP
.09903	.06602	.69986
.37651	.25101	1.41881
.77748	.51832	1.89848
1.22252	.81501	1.03833

SPANWISE PRESSURES AT CONSTANT X= 3.50000

Y	2Y/B(LOCAL)	DELTA-CP
.09903	.05659	.47866
.37651	.21515	1.01330
.77748	.44427	1.84657
1.22252	.69858	1.23076
1.62349	.92771	.99452

SPANWISE PRESSURES AT CONSTANT X= 3.75000

Y	2Y/B(LOCAL)	DELTA-CP
.09903	.05282	.64341
.37651	.20081	.81792
.77748	.41466	1.51332
1.22252	.65201	1.05705
1.62349	.86586	.46002

TOTAL ABSOLUTE FORCE ACTING ON LEADING-EDGE FREE ELEMENTS= .42133

ORIGINAL PAGE IS
OF POOR QUALITY

Similar type of output data is printed for iterations 2 through 7.

ORIGINAL PAGE IS
OF POOR QUALITY

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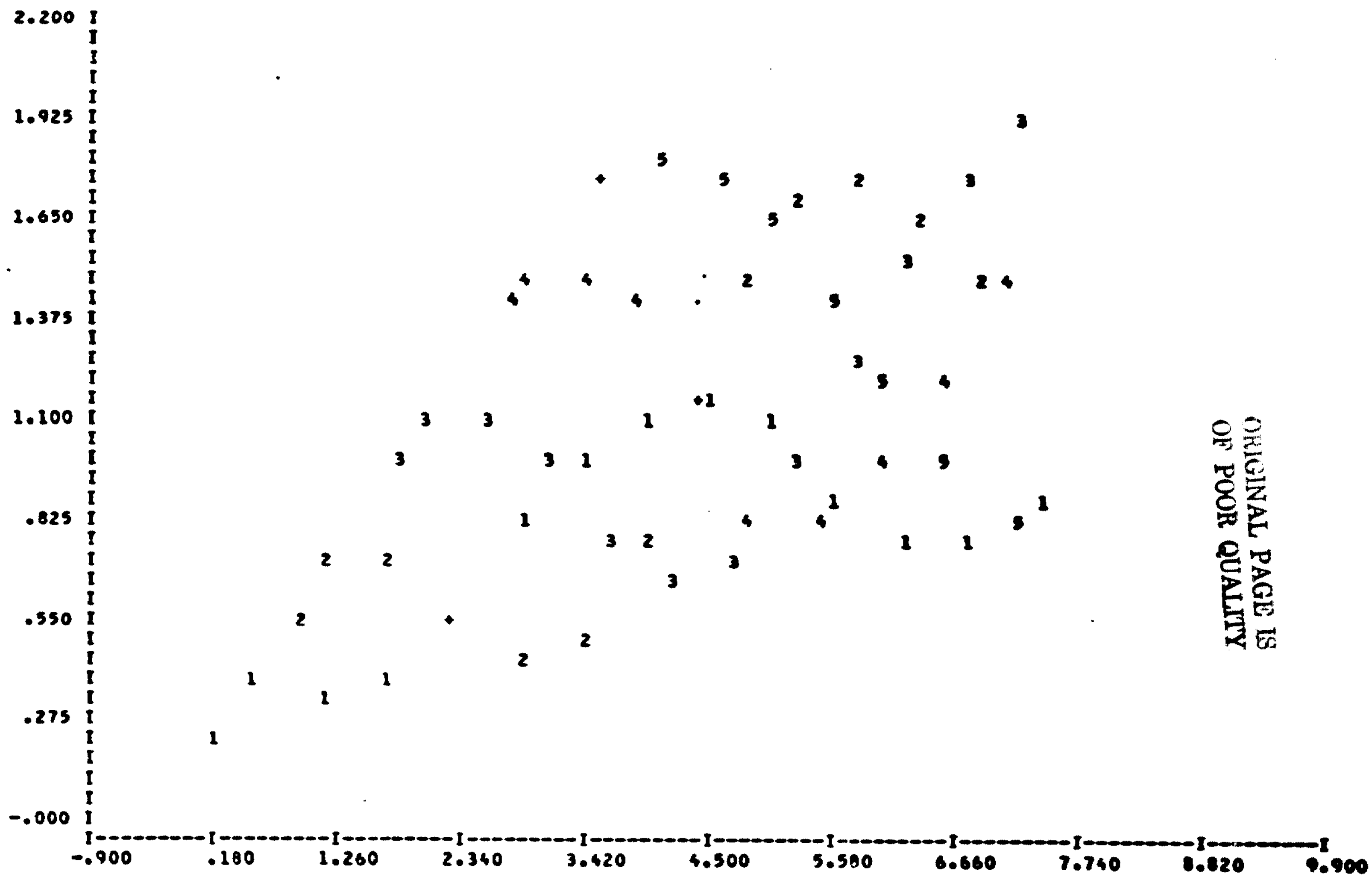
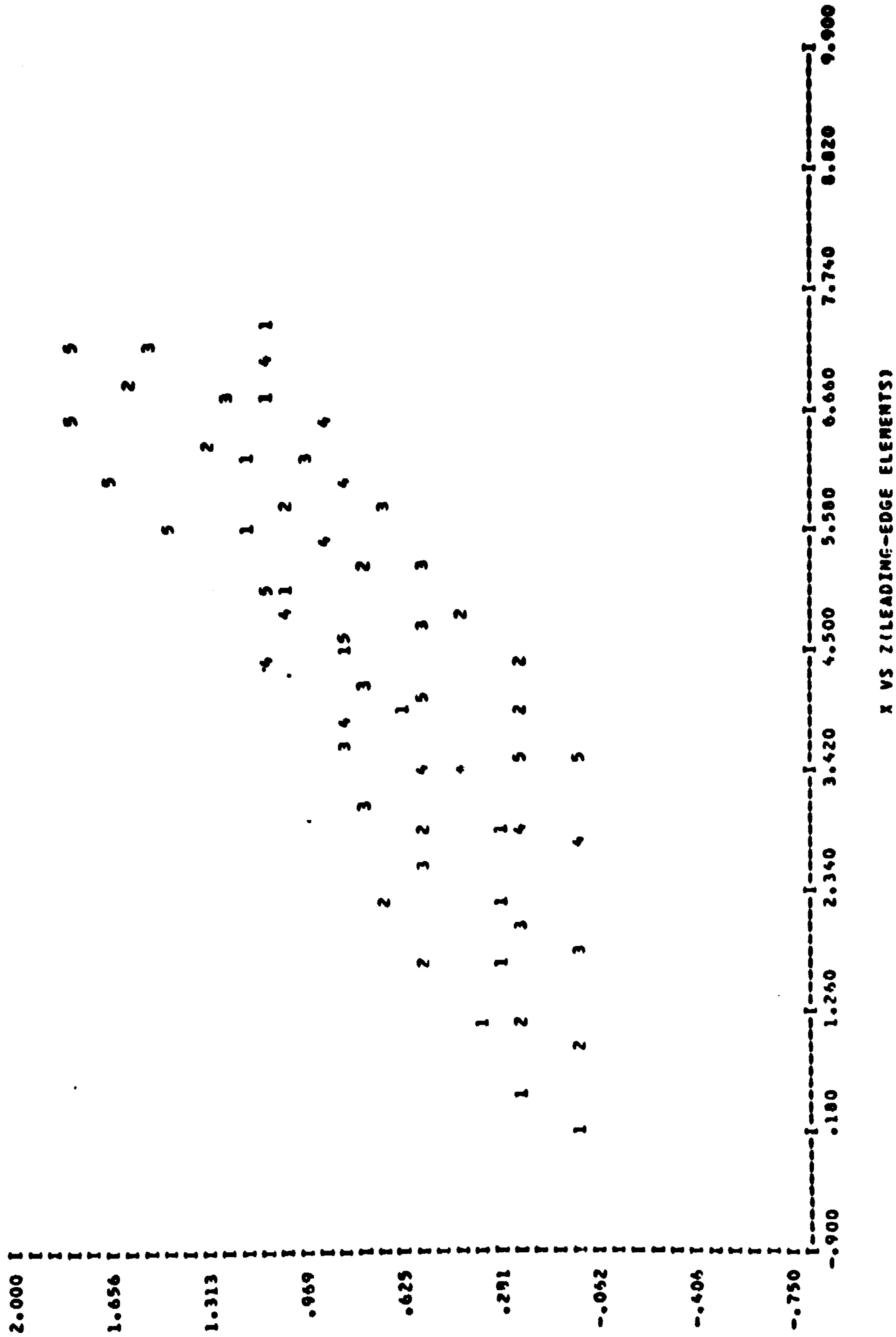
                  ASPECT RATIO = 2.0
ALPHA(DEG.)=30.000  MACH NUMBER= 0.000  ITERATION NUMBER= 8

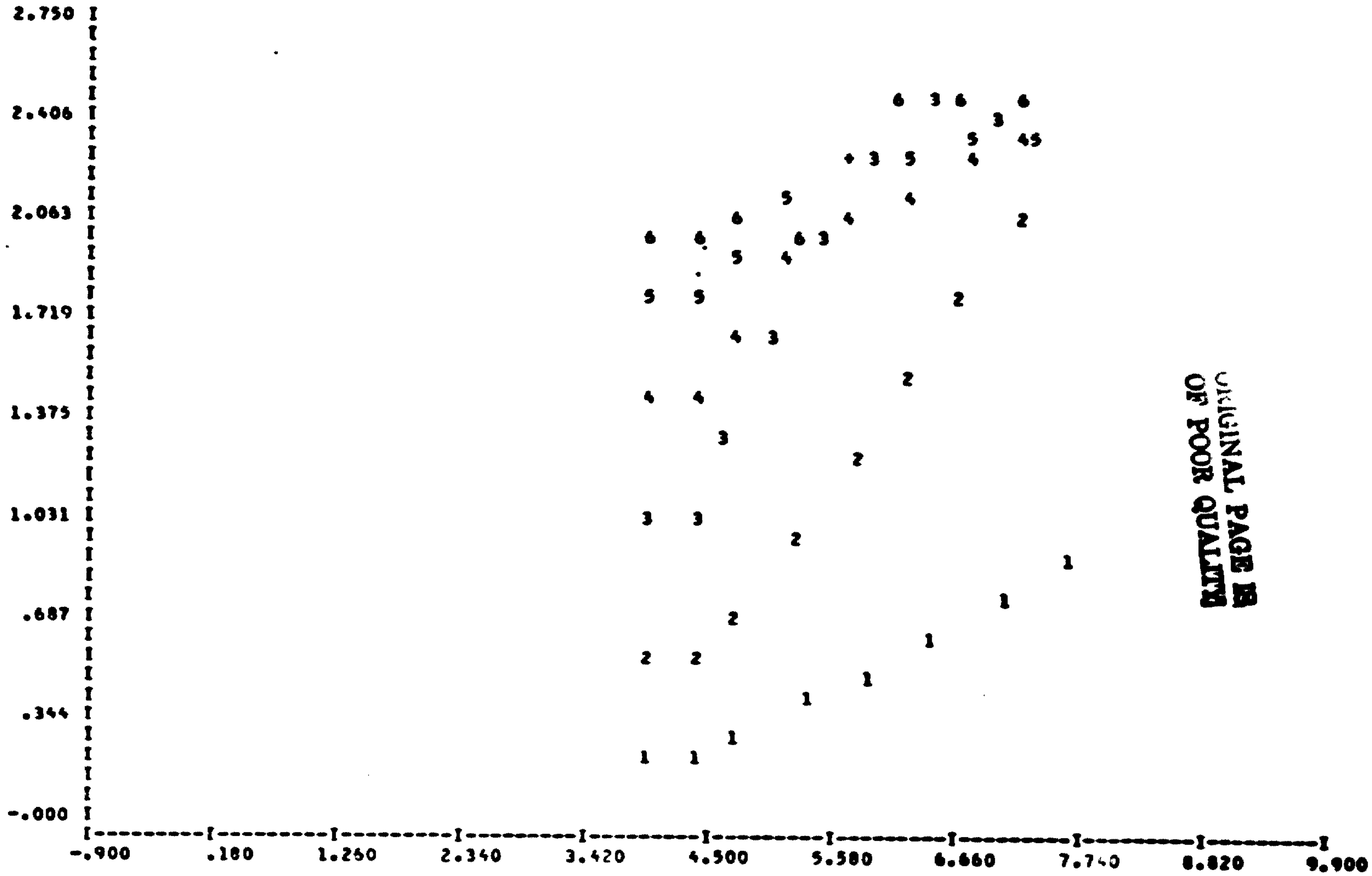
LEADING EDGE ELEMENTS
*********************
**** 1****
  4.0000    .4810    .0501   0.0000   -.2000    .2000    .7196
   .2182    .2182   0.0000   0.0000   0.0000   0.0000   0.0000
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5309
**** 2****
  4.0000   1.1682    .4810    .4363    .2582    .5650   1.1710   1.7672   2.3353   2.8862   3.4324   3.9932   4.5647   5.1110
  5.6623   6.2497   6.8483   7.4432
   .5661    .5661    .2182    .2182    .2182    .3602    .3285    .3778    .5667    .8023   1.0120   1.1187   1.1469   1.1043
   .9362    .7887    .7942    .8710
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .3558    .3103    .2705    .3024    .4353    .6199    .8005   1.0432
  1.1773   1.1488   1.1069   1.1172
**** 3****
  4.0000   2.0251   1.1682   1.1322    .9888   1.2219   1.7408   2.3013   2.8852   3.4520   3.9704   4.4306   4.8790   5.3570
  5.8736   6.3655   6.9000
  1.0000   1.0000    .5661    .5661    .5661    .7332    .7057    .5427    .4330    .4975    .7547   1.1397   1.4856   1.6890
  1.7523   1.6634   1.4875
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5309    .6696    .5856    .3995    .2412    .2379    .4342    .7342
  1.0342   1.3342   1.5879
**** 4****
  4.0000   2.8820   2.0251   2.0000   1.9000   2.0647   2.5843   3.1060   3.6644   4.2410   4.8107   5.3498   5.8446   6.3287
  6.7251   7.2939
  1.4339   1.4339   1.0000   1.0000   1.0000   1.1134   1.1207    .9813    .7743    .6542    .7287    .9888   1.2918   1.5357
  1.7840   1.9033
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5309    .7925    .8654    .7505    .5779    .5352    .6879    .9452
  1.2452   1.5452
**** 5****
  4.0000   3.5691   2.8820   2.8678   2.8112   2.9160   3.4352   3.9481   4.4050   4.9161   5.4848   6.0602   6.6140   7.1320
  1.7816   1.7818   1.4339   1.4339   1.4339   1.4766   1.4982   1.4150   1.1436    .8326    .8487   1.0159   1.2308   1.4633
  0.0000   0.0000   0.0000   0.0000   0.0000    .2309    .5309    .8309   1.1095   1.0644    .8736    .8428    .9269   1.1209
**** 6****
  4.0000   3.9505   3.5691   3.5637   3.5418   3.5838   4.1026   4.6214   5.1255   5.6052   6.1112   6.6537   7.2250
  1.9749   1.9749   1.7818   1.7818   1.7818   1.7699   1.7988   1.7683   1.6423   1.4425   1.2061    .9784    .7998
  0.0000   0.0000   0 0000   0.0000   0.0000    .2309    .5309    .8309   1.1309   1.4309   1.6501   1.7677   1.8090
```

```
WAKE ELEMENTS
*************
**** 1****
   4.0000   4.4000   4.8000   5.4000   6.0000   6.6000   7.2000   7.8000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
**** 2****
   4.0000   4.4000   4.7950   5.3837   5.9691   6.5489   7.1210   7.6835
    .2182    .2182    .2762    .3819    .4978    .6256    .7667    .9181
   0.0000   0.0000    .0241    .0720    .1345    .2209    .3340    .4778
**** 3****
   4.0000   4.4000   4.7722   5.3152   5.8277   6.3064   6.7535   7.2188
    .5661    .5661    .7118    .9591   1.2379   1.5255   1.7972   2.0284
   0.0000   0.0000   -.0152    .0480    .1880    .4030    .6998    .9998
**** 4****
   4.0000   4.4000   4.6777   5.1049   5.5289   6.0000   6.4677   6.9853
   1.0000   1.0000   1.2874   1.6665   1.9858   2.2392   2.4657   2.4202
   0.0000   0.0000    .0154    .1994    .4791    .7509   1.0509   1.3509
**** 5****
   4.0000   4.4000   4.7294   5.2543   5.7812   6.2922   6.7917   7.3062
   1.4339   1.4339   1.6403   1.9193   2.0575   2.1515   2.2946   2.3672
   0.0000   0.0000    .0943    .1759    .4275    .7275   1.0275   1.3275
**** 6****
   4.0000   4.4000   4.7569   5.2122   5.7156   6.2566   6.8245   7.3441
   1.7818   1.7818   1.9106   2.1609   2.2897   2.2532   2.3237   2.3229
   0.0000   0.0000    .1267    .4267    .7267    .9837   1.1639   1.4639
**** 7****
   4.0000   4.4000   4.7409   5.2573   5.7463   6.2053   6.7249   7.2717
   1.9749   1.9749   2.0367   1.9795   2.2496   2.4932   2.5000   2.5000
   0.0000   0.0000    .2000    .5000    .7188   1.0168   1.3188   1.5658
```

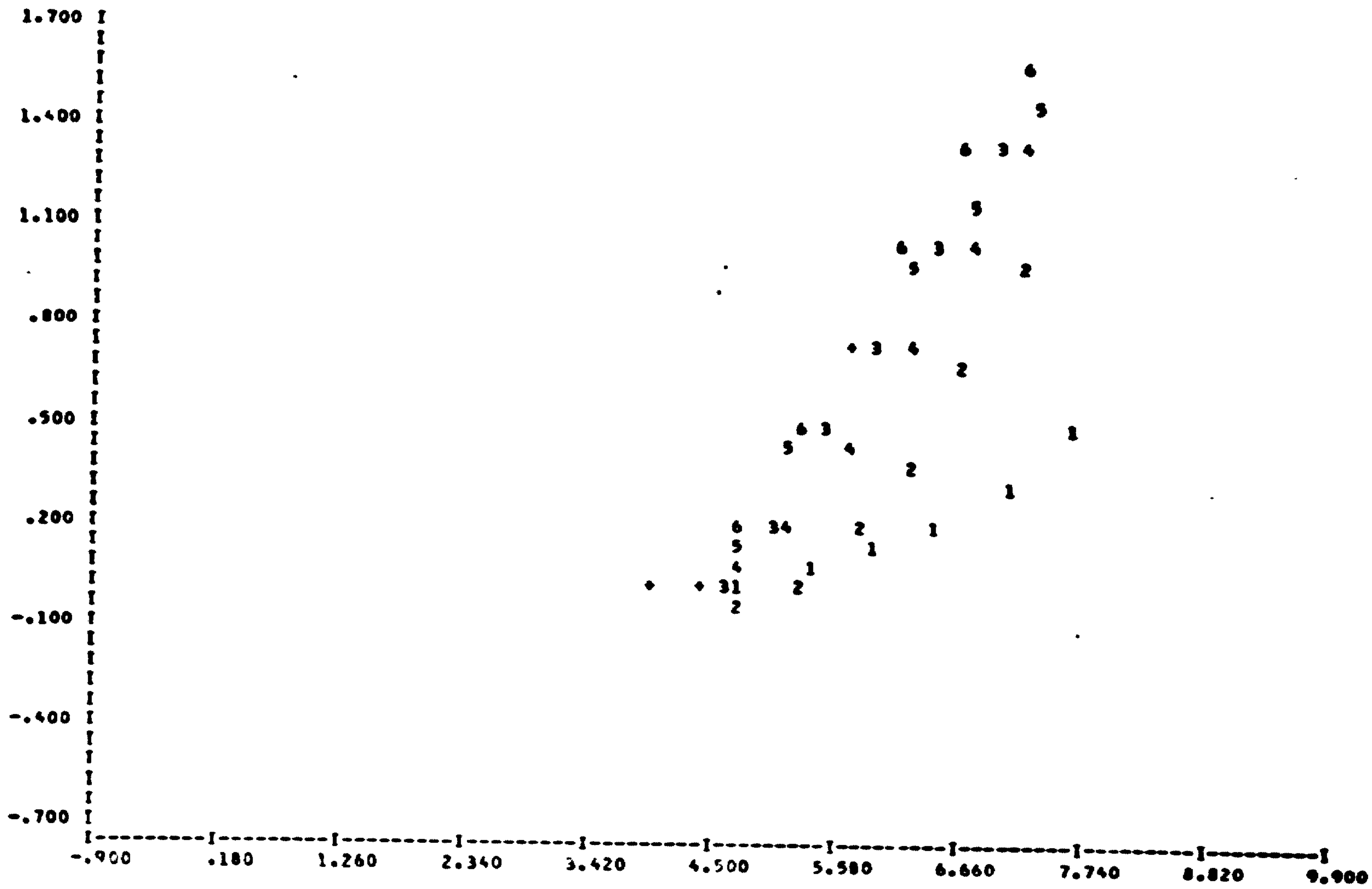


X VS Y (LEADING-EDGE ELEMENTS)


X VS Z(LEADING-EDGE ELEMENTS)
2.000
1.656
1.313
.969
.625
.281
-.062
-.406
-.750
-.900
.180
1.260
2.340
3.420
4.500
5.580
6.660
7.740
8.820
9.900



X VS Y(WAKE ELEMENTS)



X VS Z(WAKE ELEMENTS)

WING VORTEX STRENGTHS
****

X/C	2Y/B	GAMAY
***	****	*****
.01704	.04952	8.29778
.14645	.04952	1.29432
.37059	.04952	.66099
.62941	.04952	.47469
.85355	.04952	.20774
.98296	.04952	.07803
.01704	.18826	5.46306
.14645	.18826	1.03076
.37059	.18826	.54839
.62941	.18826	.47055
.85355	.18826	.16869
.98296	.18826	.04794
.01704	.38874	5.73815
.14645	.38874	.99339
.37059	.38874	.54775
.62941	.38874	.37491
.85355	.38874	.22647
.98296	.38874	-.03010
.01704	.61126	8.64016
.14645	.61126	1.01289
.37059	.61126	.72101
.62941	.61126	.45620
.85355	.61126	.28402
.98296	.61126	.09298
.01704	.81174	11.55106
.14645	.81174	1.21739
.37059	.81174	.82212
.62941	.81174	.56278
.85355	.81174	.30692
.98296	.81174	.09418
.01704	.95048	17.73351
.14645	.95048	1.80304
.37059	.95048	1.10434
.62941	.95048	.77341
.85355	.95048	.44698
.98296	.95048	.13769

LEADING-EDGE VORTICES STRENGTHS
****

2Y/B

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****	*******
.04952	1.60568
.18826	.90490
.38874	.86239
.61126	.71020
.81174	.46124
.95048	.18644

DELTA-CP DISTRIBUTION
****

X/C	2Y/B	DELTA-CP
***	****	********
.01254	.04952	7.61337
.10908	.04952	4.55513
.28306	.04952	1.52432
.50000	.04952	1.29877
.71694	.04952	.66802
.89092	.04952	.36277
.98746	.04952	.15258
.01254	.18826	6.34274
.10908	.18826	2.29859
.28306	.18826	1.73239
.50000	.18826	1.58317
.71694	.18826	1.21972
.89092	.18826	.77920
.98746	.18826	.50958
.01254	.38874	4.33651
.10908	.38874	2.91581
.28306	.38874	1.97543
.50000	.38874	1.63405
.71694	.38874	1.76146
.89092	.38874	1.44152
.98746	.38874	1.15567
.01254	.61126	3.55946
.10908	.61126	2.62342
.28306	.61126	1.33923
.50000	.61126	.97921
.71694	.61126	1.18459
.89092	.61126	.90131
.98746	.61126	.86762
.01254	.81174	3.13069
.10908	.81174	2.47576
.28306	.81174	1.27152
.50000	.81174	.73556
.71694	.81174	.48107
.89092	.81174	.22523
.98746	.81174	-.11281
.01254	.95048	2.63992
.10908	.95048	2.47422
.28306	.95048	1.11563
.50000	.95048	.74813
.71694	.95048	.15061
.89092	.95048	-.18024
.98746	.95048	-.76758

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```
SECTIONAL PROPERTIES
********************

I       CLI        CMI        CDI        CTI
*       ***        ***        ***        ***
1    1.56797   -1.04769     .90527    0.00000
2    1.49362   -1.64737     .86234    0.00000
3    1.73731   -2.58121    1.00304    0.00000
4    1.25071   -2.19754     .72210    0.00000
5     .90756   -1.80956     .52399    0.00000
6     .72602   -1.60837     .41917    0.00000

TOTAL LIFT COEFFICIENT=    1.45997
TOTAL PITCHING MOMENT COEFFICIENT=   -1.86231
TOTAL DRAG COEFFICIENT=     .84292
TOTAL THRUST COEFFICIENT=    0.00000

SPANWISE PRESSURES AT CONSTANT X=    1.00000
      Y     2Y/B(LOCAL) DELTA-CP
    .09903     .19806     2.34285
    .37651     .75302     2.68275

SPANWISE PRESSURES AT CONSTANT X=    2.00000
      Y     2Y/B(LOCAL) DELTA-CP
    .09903     .09903     1.28618
    .37651     .37651     1.66734
    .77748     .77748     2.47956

SPANWISE PRESSURES AT CONSTANT X=    3.00000
      Y     2Y/B(LOCAL) DELTA-CP
    .09903     .06602      .57516
    .37651     .25101     1.27410
    .77748     .51832     1.69580
   1.22252     .81501     1.06014

SPANWISE PRESSURES AT CONSTANT X=    3.50000
      Y     2Y/B(LOCAL) DELTA-CP
    .09903     .05659      .31908
    .37651     .21515      .89992
    .77748     .44427     1.69872
   1.22252     .69858     1.17457
   1.62349     .92771     1.05241
```

SPANWISE PRESSURES AT CONSTANT X= 3.75000

Y	2Y/B(LOCAL)	DELTA-CP
.09903	.05282	.47436
.37651	.20081	.68765
.77748	.41466	1.41464
1.22252	.65201	1.03999
1.62349	.86586	.55153

TOTAL ABSOLUTE FORCE ACTING ON LEADING-EDGE FREE ELEMENTS= .17432

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Similar type of output data is printed for iterations 9 and 10.

SUMMARY SHEET
****

ASPECT RATIO = 2.0

ALPHA(DEG.)=30.000 MACH NUMBER= 0.000

ITERATION	CL	CM	CD	CT	GMSUM	PERR	TFABS
*********	**	**	**	**	*****	****	*****
0	1.5581	-1.8319	.8995	0.0000	3.2626		1.2862
1	1.6609	-2.0734	.9589	0.0000	3.2710	.2571	.4213
2	1.5024	-1.9132	.8674	0.0000	3.1577	3.5233	.3423
3	1.4260	-1.8073	.8233	0.0000	3.1057	1.6609	.3454
4	1.4328	-1.8182	.8272	0.0000	3.1027	.0976	.2999
5	1.4558	-1.8541	.8405	0.0000	3.1204	.5712	.2140
6	1.4632	-1.8670	.8448	0.0000	3.1257	.1698	.1865
7	1.4648	-1.8697	.8457	0.0000	3.1292	.1117	.1858
8	1.4600	-1.8623	.8429	0.0000	3.1252	.1308	.1743
9	1.4598	-1.8618	.8428	0.0000	3.1260	.0263	.1754
10	1.4598	-1.8614	.8428	0.0000	3.1270	.0318	.1732

ALL CASES COMPLETED

6.2 APPENDIX B: COMPUTER PROGRAM LISTING

A listing of the computer program is given on the following pages.

```
      OVERLAY (LEVSP,0,0)
      PROGRAM LEVSP(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3,TAPE5=INPUT,TAPE6=OUT
     1PUT,PUNCH,TAPE4,TAPE7)
C
C     AERODYNAMICS OF LOW ASPECT-RATIO WINGS WITH PARTIAL LEADING-EDGE
C     SEPARATION (LEADING-EDGE VORTEX SEPARATION PROGRAM)
C     BY - SUDHIR C. MEHROTRA AND C. EDWARD LAN
C          UNIVERSITY OF KANSAS
C
C     THIS PROGRAM IS RESTRICTED TO DELTA AND ARROW WINGS
C
C     PROGRAM IS DIVIDED INTO FIVE OVERLAYS.
C     OVERLAY (1,0) READS ALL THE DATA CARDS AND SETSUP INETIAL GEOMETRY
C                   OF THE WING AND THE FREE ELEMENTS
C     OVERLAY (2,0) PLOTS FREE ELEMENTS OVER THE WING AND IN THE WAKE ON
C                   THE LINE PRINTER OUTPUT
C     OVERLAY (3,0) SOLVES FOR THE STRENGTHS OF WING AND LEADING-EDGE
C                   VORTEX SYSTEM
C     OVERLAY (4,0) COMPUTES THE AERODYNAMIC CHARACTERSTICS
C     OVERLAY (5,0) COMPUTES THE NEW LOCATIONS OF THE LEADING-EDGE AND
C                   TRAILING-EDGE VORTICES
C     AS THE PROBLEM IS NONLINEAR, IT IS SOLVED BY ITERATION. ITERATION
C     IS PERFORMED OVER OVERLAYS (2,0) THRU (4,0) TO OBTAIN THE FINAL
C     CONVERGED SOLUTION.
C
C     THE DIMENSIONS OF THE FOLLOWING VARIABLES MUST BE CHECKED BEFORE
C     RUNNING THE PROGRAM.
C
C     -D- APPEARS IN BLANK COMMON OF MAIN LINE (OVERLAY(0,0))
C         MUST BE DIMENSIONED MAXIMUM OF THE FOLLOWING VARIABLES.
C         N1=2286
C         N2=3*NMAX*(NSW-1)+NSW
C         N3=3*NSW*(NNMAX+2)+NSW+1
C         N4=(NCPTTL+1)**2/4+10*NWNG+10*NSW+3*NCW-6
C         N5=28*NWNG+25*NSW+10*NCW-14
C         N6=21*NWNG+14*NSW+NCW-9
C
C     -W- APPEARS IN PROGRAM LOADS (OVERLAY(4,0))
C         MUST BE DIMENSIONED AT LEAST ((NWNG+NCW+3)*(NWNG+NCW+4))
C
```

```
C      -E- APPEARS IN PROGRAM NEWSHAP (OVERLAY(5,0))
C          MUST BE DIMENSIONED AT LEAST (3*NSW*(NMAX+NNMAX)-3*NMAX+1)
C
C          WHERE,NMAX    = MAXIMUM NUMBER OF END-POINTS IN ANY ONE FREE
C                          LEADING-EDGE VORTEX ELEMENT
C                 NNMAX  = MAXIMUM NUMBER OF END-POINTS IN ANY ONE WAKE
C                          ELEMENT
C                 NCW    = NUMBER OF CHORDWISE LINES
C                 NSW    = NUMBER OF SPANWISE LINES (ONE HIGHER THAN
C                          NUMBER OF SPANWISE ROWS OF PANELS)
C                 NCPTTL = TOTAL NUMBER OF CONTROL POINTS OVER THE WING
C                          INCLUDING THOSE AT THE LEADING-EDGE ((NCW+1)*
C                          (NSW-1))
C                 NWNG   = TOTAL NUMBER OF CONTROL POINTS OVER THE WING
C                          EXCLUDING THOSE AT THE LEADING-EDGE (NCW*
C                          (NSW-1))
C
       COMMON D(3000)
       COMMON /ALLI/ NSW,NSW1,NCW,NWNG,NCPTTL,MITER,IPUNCH
       COMMON /ALLRA/ TTL(16),ALPHA,SINA,COSA,SWPLE,BETA,BETA2,TANPH1,B2P
      1H1,BSQD4P,D4,CON,PI,D4SQ2,CBAR,HALFB,AREA
       COMMON /ALLRB/ XE(40),YE(40),ZE(40),XXE(30),YYE(30),ZZE(30),ZMIN,N
      1ELM(11),NNELM(12)
       COMMON /XPLOT/ XMN,YMN,ZMN,XMX,YMX,ZMX
       COMMON /GM/ ITER,L1,L2,L3,L4,L5,L6,L7,L8
       COMMON /XSTN/ XBRR(25),NBRK
10     CALL OVERLAY (5HLEVSP,1,0)
       ITER=0
20     CONTINUE
       ALP=ALPHA*180./PI
       AMACH=SQRT(1.-BETA2)
C      WRITE FREE ELEMENTS LOCATIONS
       WRITE (6,100) TTL,ALP,AMACH,ITER
       REWIND 4
       DO 30 I=1,NSW1
C      ****************************************************************
       READ (4) K,(XE(J),YE(J),ZE(J),J=1,K)
C      ****************************************************************
       WRITE (6,150) I
```

```
      WRITE (6,140) (XE(J),J=1,K)                                       LEV 800
      WRITE (6,140) (YE(J),J=1,K)                                       LEV 810
   30 WRITE (6,140) (ZE(J),J=1,K)                                       LEV 820
      WRITE (6,180)                                                     LEV 830
      DO 40 I=1,NSW                                                     LEV 840
C     *****************************************************************LEV 850
      READ (4) K,(XXE(J),YYE(J),ZZE(J),J=1,K)                           LEV 860
C     *****************************************************************LEV 870
      WRITE (6,150) I                                                   LEV 880
      WRITE (6,140) (XXE(J),J=1,K)                                      LEV 890
      WRITE (6,140) (YYE(J),J=1,K)                                      LEV 900
   40 WRITE (6,140) (ZZE(J),J=1,K)                                      LEV 910
      CALL OVERLAY (5HLEVSP,2,0)                                        LEV 920
      CALL OVERLAY (5HLEVSP,3,0)                                        LEV 930
      CALL OVERLAY (5HLEVSP,4,0)                                        LEV 940
      CALL OVERLAY (5HLEVSP,5,0)                                        LEV 950
      ITER=ITER+1                                                       LEV 960
      IF (ITER.LE.MITER) GO TO 20                                       LEV 970
      IF (IPUNCH.EQ.0) GO TO 70                                         LEV 980
C     PUNCH-OUT FREE ELEMENTS LOCATIONS AFTER LAST ITERATION            LEV 990
      REWIND 4                                                          LEV1000
C                                                                       LEV1010
      PUNCH 170, (NELM(I),I=1,NSW1)                                     LEV1020
      DO 50 I=1,NSW1                                                    LEV1030
C     *****************************************************************LEV1040
      READ (4) K,(XE(J),YE(J),ZE(J),J=1,K)                              LEV1050
C     *****************************************************************LEV1060
      PUNCH 160, (XE(J),J=1,K)                                          LEV1070
      PUNCH 160, (YE(J),J=1,K)                                          LEV1080
   50 PUNCH 160, (ZE(J),J=1,K)                                          LEV1090
      PUNCH 170, (NNELM(I),I=1,NSW)                                     LEV1100
      DO 60 I=1,NSW                                                     LEV1110
C     *****************************************************************LEV1120
      READ (4) K,(XXE(J),YYE(J),ZZE(J),J=1,K)                           LEV1130
C     *****************************************************************LEV1140
      PUNCH 160, (XXE(J),J=1,K)                                         LEV1150
      PUNCH 160, (YYE(J),J=1,K)                                         LEV1160
   60 PUNCH 160, (ZZE(J),J=1,K)                                         LEV1170
C     FORMULATION OF SUMMARY SHEET                                      LEV1180
```

```
70    REWIND 7                                                          LEV1190
      WRITE (6,110) TTL,ALP,AMACH                                       LEV1200
      MIT=MITER+1                                                       LEV1210
      GM1=0.                                                            LEV1220
      DO 90 I=1,MIT                                                     LEV1230
      J=I-1                                                             LEV1240
C     ******************************************************************LEV1250
      READ (7) GMSUM                                                    LEV1260
      READ (7) CL,CM,CD,CTT                                             LEV1270
      READ (7) TFABS,TAVRG,TLNTH                                        LEV1280
C     ******************************************************************LEV1290
      GM2=GMSUM                                                         LEV1300
      PERR=200.0*(ABS(GM1-GM2))/(GM1+GM2)                               LEV1310
      GM1=GM2                                                           LEV1320
      IF (I.EQ.1) GO TO 80                                              LEV1330
      WRITE (6,120) J,CL,CM,CD,CTT,GMSUM,PERR,TFABS                     LEV1340
      GO TO 90                                                          LEV1350
80    WRITE (6,130) J,CL,CM,CD,CTT,GMSUM,TFABS                          LEV1360
90    CONTINUE                                                          LEV1370
      GO TO 10                                                          LEV1380
C                                                                       LEV1390
C                                                                       LEV1400
100   FORMAT (1H1,//,16A5,/,1X,12HALPHA(DEG.)=,F6.3,14H  MACH NUMBER=,F6LEV1410
     1.3,19H  ITERATION NUMBER=,I2,//,1X,21HLEADING EDGE ELEMENTS,/,1X,2LEV1420
     21H*********************)                                          LEV1430
110   FORMAT (1H1,//,23X,13HSUMMARY SHEET,/,23X,13H*************,//,1X,1LEV1440
     16A5,//,2X,12HALPHA(DEG.)=F6.3,14H  MACH NUMBER=,F6.3,//,66H  ITERALEV1450
     2TION    CL       CM       CD       CT     GMSUM    PERR   TFABS,/,66H LEV1460
     3 *********     **       **       **       **     *****    ****   *****)LEV1470
120   FORMAT (I7,4X,7F8.4)                                              LEV1480
130   FORMAT (I7,4X,5F8.4,8X,F8.4)                                      LEV1490
140   FORMAT (14F9.4)                                                   LEV1500
150   FORMAT (5H ****,I2,4H****)                                        LEV1510
160   FORMAT (10F8.5)                                                   LEV1520
170   FORMAT (10I2)                                                     LEV1530
180   FORMAT (1H1,//,14H WAKE ELEMENTS,/,14H *************)             LEV1540
      END                                                               LEV1550-
```

```
      SUBROUTINE SKIPR (NT,NR)
C     SKIPS NR-RECORDS OF TAPE NT
      DO 10 I=1,NR
10    READ (NT)
      RETURN
      END
```

```
      FUNCTION ARCOS (X)
C     CALCULATES ARC-COSINE OF X
      ARCOS=0.
      IF (X.EQ.1.) RETURN
      IF (X.EQ.(-1.)) GO TO 10
      XX=X/(SQRT(1.-X*X))
      ARCOS=1.5707963-ATAN(XX)
      RETURN
10    ARCOS=3.1415926
      RETURN
      END
```

```
      SUBROUTINE DOTPRO (A,B,SUM)                                       DOT  10
C     CALCULATES DOT-PRODUCT OF TWO VECTORS                             DOT  20
      DIMENSION A(3), B(3)                                              DOT  30
      SUM=0.                                                            DOT  40
      DO 10 I=1,3                                                       DOT  50
   10 SUM=SUM+A(I)*B(I)                                                 DOT  60
      RETURN                                                            DOT  70
      END                                                               DOT  80
```

```
      SUBROUTINE CRSPRD (A,B,C)                                         CRS  10
C     CALCULATES CROSS-PRODUCT OF TWO VECTORS                           CRS  20
      DIMENSION A(3), B(3), C(3)                                        CRS  30
      C(1)=A(2)*B(3)-A(3)*B(2)                                          CRS  40
      C(2)=A(3)*B(1)-A(1)*B(3)                                          CRS  50
      C(3)=A(1)*B(2)-A(2)*B(1)                                          CRS  60
      RETURN                                                            CRS  70
      END                                                               CRS  80-
```

```
      SUBROUTINE VDTWNG (C,THETP,XX,YY,ZZ,XN,YN,XTE,YTE,CONS,CONI1,CONI3
     1,CONJ1,CONJ2,CONJ3,CONK1,CONK2,CONK3,CONI,CONJ,CONK,SI,NSW1,NCW,NW
     2NG)
C     EVALUATES INFLUENCE COEFFICIENTS FOR CALCULATION OF INDUCED
C     VELOCITY DUE TO WING ELEMENTS
      COMMON /ALLI/ NSW
      COMMON /ALLRB/ XXE(30),YYE(30),ZZE(30)
      COMMON /NCTT/ NCT,NCON
      COMMON /XIYIZI/ XI,YI,ZI
      DIMENSION THETP(1), C(1), CONS(1), XTE(1), YTE(1), SI(1), CONI1(1)
     1, CONI3(1), CONJ1(1), CONJ2(1), CONJ3(1), CONK1(1), CONK2(1), CONK
     23(1), CONI(1), CONJ(1), CONK(1), XN(NWNG,2), YN(NWNG,2), B(3), D(3
     3)
C     DIMENSIONS OF FJ1,FJ2,FJ3-(2*NSW)   ** SEE GEOM **
C     DIMENSIONS OF FI2,FI3-(2*NCPTTL)  ** SEE GEOM **
      DIMENSION FJ1(40), FJ2(40), FJ3(40), FI2(418), FI3(418)
      XI=XX
      YI=YY
      ZI=ZZ
      NC1=NWNG+NCW
      NC2=NWNG-NCW
C     VELOCITY DUE TO BOUND ELEMENTS
      DO 10 I=1,NSW1
      DO 10 J=1,NCW
      NP=(I-1)*NCW+J
      CALL INFL2 (XN(NP,1),YN(NP,1),0.,XN(NP,2),YN(NP,2),0.,B)
      A1=-YN(NP,1)
      A2=-YN(NP,2)
      CALL INFL2 (XN(NP,1),A1,0.,XN(NP,2),A2,0.,D)
      CONI(NP)=CONS(I)*(B(1)-D(1))
      CONJ(NP)=CONS(I)*(B(2)-D(2))
   10 CONK(NP)=CONS(I)*(B(3)-D(3))
C     VELOCITY DUE TO TRAILING ELEMENTS ON THE WING SURFACE
      DO 20 I=1,NSW1
      DO 20 J=1,NCW
      NP=(I-1)*NCW+J
      CALL INFL2 (XN(NP,1),YN(NP,1),0.,XTE(I),YN(NP,1),0.,B)
      FI2(NP)=B(2)
      FI3(NP)=B(3)
      AYN=-YN(NP,1)
```

```
      NQ=NC1+NP                                                         WNG 410
      CALL INFL2 (XN(NP,1),AYN,0.,XTE(I),AYN,0.,B)                      WNG 420
      FI2(NQ)=B(2)                                                      WNG 430
      FI3(NQ)=B(3)                                                      WNG 440
20    CONTINUE                                                          WNG 450
      DO 30 J=1,NCW                                                     WNG 460
      NP1=NWNG+J                                                        WNG 470
      NP2=NC1+NP1                                                       WNG 480
      NP=NC2+J                                                          WNG 490
      CALL INFL2 (XN(NP,2),YN(NP,2),0.,XTE(NSW),YN(NP,2),0.,B)          WNG 500
      FI2(NP1)=B(2)                                                     WNG 510
      FI3(NP1)=B(3)                                                     WNG 520
      AYN=-YN(NP,2)                                                     WNG 530
      CALL INFL2 (XN(NP,2),AYN,0.,XTE(NSW),AYN,0.,B)                    WNG 540
      FI2(NP2)=B(2)                                                     WNG 550
      FI3(NP2)=B(3)                                                     WNG 560
30    CONTINUE                                                          WNG 570
      DO 40 I=1,NSW1                                                    WNG 580
      DO 40 J=1,NCW                                                     WNG 590
      NP=(I-1)*NCW+J                                                    WNG 600
      I1=NP+NC1                                                         WNG 610
      I2=NP+NCW                                                         WNG 620
      I3=I1+NCW                                                         WNG 630
      CONJ2(NP)=CONS(I)*(FI2(I1)-FI2(NP)+FI2(I2)-FI2(I3))               WNG 640
40    CONK2(NP)=CONS(I)*(FI3(I1)-FI3(NP)+FI3(I2)-FI3(I3))               WNG 650
C     VELOCITY DUE TO TRAILING ELEMENTS BEYOND TRAILING EDGE            WNG 660
C     ******************************************************************WNG 670
      REWIND 4                                                          WNG 680
      CALL SKIPR (4,NSW)                                                WNG 690
      DO 80 I=2,NSW                                                     WNG 700
      READ (4) KK,(XXE(J),YYE(J),ZZE(J),J=1,KK)                         WNG 710
C     ******************************************************************WNG 720
      FJ1(I)=0.                                                         WNG 730
      FJ2(I)=0.                                                         WNG 740
      FJ3(I)=0.                                                         WNG 750
      IF (I.EQ.NCT) GO TO 60                                            WNG 760
      DO 50 J=2,KK                                                      WNG 770
      CALL INFL2 (XXE(J-1),YYE(J-1),ZZE(J-1),XXE(J),YYE(J),ZZE(J),B)    WNG 780
      FJ1(I)=FJ1(I)+B(1)                                                WNG 790
```

```
      FJ2(I)=FJ2(I)+B(2)                                                WNG 800
      FJ3(I)=FJ3(I)+B(3)                                                WNG 810
   50 CONTINUE                                                          WNG 820
      CALL FUNA (XXE(KK),YYE(KK),ZZE(KK),B(1),B(2),B(3))                WNG 830
      FJ1(I)=FJ1(I)+B(1)                                                WNG 840
      FJ2(I)=FJ2(I)+B(2)                                                WNG 850
      FJ3(I)=FJ3(I)+B(3)                                                WNG 860
   60 CONTINUE                                                          WNG 870
      IN=I+NSW                                                          WNG 880
      FJ1(IN)=0.                                                        WNG 890
      FJ2(IN)=0.                                                        WNG 900
      FJ3(IN)=0.                                                        WNG 910
      DO 70 J=2,KK                                                      WNG 920
      AYT1=-YYE(J-1)                                                    WNG 930
      AYT2=-YYE(J)                                                      WNG 940
      CALL INFL2 (XXE(J-1),AYT1,ZZE(J-1),XXE(J),AYT2,ZZE(J),B)          WNG 950
      FJ1(IN)=FJ1(IN)+B(1)                                              WNG 960
      FJ2(IN)=FJ2(IN)+B(2)                                              WNG 970
      FJ3(IN)=FJ3(IN)+B(3)                                              WNG 980
   70 CONTINUE                                                          WNG 990
      AYT2=-YYE(KK)                                                     WNG1000
      CALL FUNA (XXE(KK),AYT2,ZZE(KK),B(1),B(2),B(3))                   WNG1010
      FJ1(IN)=FJ1(IN)+B(1)                                              WNG1020
      FJ2(IN)=FJ2(IN)+B(2)                                              WNG1030
      FJ3(IN)=FJ3(IN)+B(3)                                              WNG1040
   80 CONTINUE                                                          WNG1050
      FJ1(1)=0.                                                         WNG1060
      FJ2(1)=0.                                                         WNG1070
      FJ3(1)=0.                                                         WNG1080
      FJ1(NSW+1)=0.                                                     WNG1090
      FJ2(NSW+1)=0.                                                     WNG1100
      FJ3(NSW+1)=0.                                                     WNG1110
      DO 90 I=1,NSW1                                                    WNG1120
      I1=I+1                                                            WNG1130
      I2=I+NSW                                                          WNG1140
      I3=I2+1                                                           WNG1150
      EFJ1=CONS(I)*(FJ1(I2)-FJ1(I)+FJ1(I1)-FJ1(I3))                     WNG1160
      EFJ2=CONS(I)*(FJ2(I2)-FJ2(I)+FJ2(I1)-FJ2(I3))                     WNG1170
      EFJ3=CONS(I)*(FJ3(I2)-FJ3(I)+FJ3(I1)-FJ3(I3))                     WNG1180
```

```
      DO 90 J=1,NCW
      NP=(I-1)*NCW+J
      CONI3(NP)=EFJ1
      CONJ3(NP)=EFJ2
90    CONK3(NP)=EFJ3
C     TOTAL INDUCED VELOCITY
      I=1
      DO 100 J=1,NWNG
      CONI(J)=(CONI(J)+CONI3(J))*SI(I)
      CONJ(J)=(CONJ(J)+CONJ2(J)+CONJ3(J))*SI(I)
      CONK(J)=(CONK(J)+CONK2(J)+CONK3(J))*SI(I)
      I=I+1
      IF (I.GT.NCW) I=1
100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE VDTFRE (X,Y,Z,CI,CJ,CK,NSW1,BSQD4P,XLE,YLE)             FRE  10
C     EVALUATES INFLUENCE COEFFICIENTS FOR CALCULATION OF INDUCED        FRE  20
C     VELOCITY DUE TO FREE ELEMENTS                                      FRE  30
      COMMON /ALLRB/ XE(40),YE(40),ZE(40),XXE(30),YYE(30),ZZE(30)       FRE  40
      COMMON /NCTT/ NCT,NCON                                             FRE  50
      COMMON /XIYIZI/ XI,YI,ZI                                           FRE  60
      DIMENSION CI(1), CJ(1), CK(1), XLE(1), YLE(1), V(3), VVV(3)        FRE  70
C     DIMENSION OF VTOL-(NSW1,3)  ** SEE GEOM **                         FRE  80
      DIMENSION VTOL(19,3)                                               FRE  90
      XI=X                                                               FRE 100
      YI=Y                                                               FRE 110
      ZI=Z                                                               FRE 120
      NCT1=0                                                             FRE 130
C     *****************************************************************FRE 140
10    REWIND 4                                                           FRE 150
C     *****************************************************************FRE 160
      DO 60 I=1,NSW1                                                     FRE 170
      V(1)=0.                                                            FRE 180
      V(2)=0.                                                            FRE 190
      V(3)=0.                                                            FRE 200
      FJ1=0.                                                             FRE 210
      FJ2=0.                                                             FRE 220
      FJ3=0.                                                             FRE 230
C     *****************************************************************FRE 240
      READ (4) KK,(XE(J),YE(J),ZE(J),J=1,KK)                             FRE 250
C     *****************************************************************FRE 260
      K=KK-1                                                             FRE 270
C     VELOCITY DUE TO FREE ELEMENTS AHEAD OF TRAILING-EDGE AND THOSE     FRE 280
C     OVER THE WING                                                      FRE 290
      DO 20 J=1,K                                                        FRE 300
      IF (I.EQ.NCON.AND.J.GT.4.AND.YI.GT.0.) GO TO 20                    FRE 310
      CALL INFL2 (XE(J),YE(J),ZE(J),XE(J+1),YE(J+1),ZE(J+1),VVV)         FRE 320
      V(1)=V(1)+VVV(1)                                                   FRE 330
      V(2)=V(2)+VVV(2)                                                   FRE 340
      V(3)=V(3)+VVV(3)                                                   FRE 350
20    CONTINUE                                                           FRE 360
      IF (I.EQ.NCON.AND.YI.GT.0.) GO TO 30                               FRE 370
      CALL FUNA (XE(K+1),YE(K+1),ZE(K+1),FJ1,FJ2,FJ3)                    FRE 380
30    VTOL(I,1)=V(1)+FJ1                                                 FRE 390
      VTOL(I,2)=V(2)+FJ2                                                 FRE 400
```

```
      VTDL(I,3)=V(3)+FJ3
      FJ1=0.
      FJ2=0.
      FJ3=0.
      I1=I+1
C     ******************************************************************
      CALL SKIPR (4,NSW1)
      READ (4) II,(XXE(J),YYE(J),ZZE(J),J=1,II)
C     ******************************************************************
      IF (I1.EQ.NCT.AND.YI.GT.0.) GO TO 50
C     VELOCITY DUE TO WAKE ELEMENTS
      DO 40 J=2,II
      CALL INFL2 (XXE(J-1),YYE(J-1),ZZE(J-1),XXE(J),YYE(J),ZZE(J),V)
      FJ1=FJ1+V(1)
      FJ2=FJ2+V(2)
      FJ3=FJ3+V(3)
40    CONTINUE
      CALL FUNA (XXE(II),YYE(II),ZZE(II),V(1),V(2),V(3))
      FJ1=FJ1+V(1)
      FJ2=FJ2+V(2)
      FJ3=FJ3+V(3)
50    CONTINUE
      VTDL(I,1)=VTDL(I,1)-FJ1
      VTDL(I,2)=VTDL(I,2)-FJ2
      VTDL(I,3)=VTDL(I,3)-FJ3
C     ******************************************************************
      REWIND 4
      CALL SKIPR (4,I)
C     ******************************************************************
60    CONTINUE
      YI=-YI
      NCT1=NCT1+1
      IF (NCT1.GT.1) GO TO 80
      DO 70 I=1,NSW1
      CI(I)=VTDL(I,1)
      CJ(I)=VTDL(I,2)
      CK(I)=VTDL(I,3)
70    CONTINUE
      GO TO 10
```

```
C     TOTAL INDUCED VELOCITY                                            FRE 800
80    DO 90 I=1,NSW1                                                    FRE 810
      CI(I)=BSQD4P*(CI(I)+VTDL(I,1))                                    FRE 820
      CJ(I)=BSQD4P*(CJ(I)-VTDL(I,2))                                    FRE 830
90    CK(I)=BSQD4P*(CK(I)+VTDL(I,3))                                    FRE 840
      RETURN                                                            FRE 850
      END                                                               FRE 860
```

```
      SUBROUTINE FUNA (XT,YT,ZT,FJ1,FJ2,FJ3)
C     INDUCED VELOCITY DUE TO A VORTEX ELEMENT OF UNIT STRENGTH TRAILING
C     FROM (XT,YT,ZT) TO INFINITY
      COMMON /ALLRA/ AA(21),BETA2,TANPH1,B2PH1,AB,D4,AC(2),D4SO2
      COMMON /XIYIZI/ XI,YI,ZI
      DIMENSION A(3), B(3), C(3)
      A(1)=XT-XI
      A(2)=YT-YI
      A(3)=ZT-ZI
      B(1)=XT+1-XI
      B(2)=YT-YI
      B(3)=ZT+TANPH1-ZI
      CALL CRSPRD (A,B,C)
      CC=SQRT(C(1)*C(1)+C(2)*C(2)+C(3)*C(3))
      IF (CC.LE.(1.E-10)) GO TO 10
      D5=2.*(B2PH1*(ZT-ZI-XT*TANPH1)-XI)
      D6=XI*XI+BETA2*((YI-YT)**2+(ZT-ZI-XT*TANPH1)**2)
      Q=4.*D4*D6-D5*D5
      IF (Q.LE.(1.E-10)) GO TO 10
      RB=SQRT(D4*XT*XT+D5*XT+D6)
      FJ4=2.*(D4SO2-(2.*D4*XT+D5)/RB)/Q
      FJ1=(YT-YI)*TANPH1*FJ4
      FJ2=(ZT-ZI+(XI-XT)*TANPH1)*FJ4
      FJ3=-(YT-YI)*FJ4
      RETURN
   10 FJ1=0.
      FJ2=0.
      FJ3=0.
      RETURN
      END
```

```
      SUBROUTINE INFL2 (X1,Y1,Z1,X2,Y2,Z2,VACL)
C     INDUCED VELOCITY DUE TO A VORTEX ELEMENT OF UNIT STRENGTH LYING
C     BETWEEN (X1,Y1,Z1) AND (X2,Y2,Z2)
      COMMON /ALLRA/ AA(20),BETA
      COMMON /XIYIZI/ XI,YI,ZI
      DIMENSION VA(3), VL(3), VAP(3), VBP(3), VLP(3), VACL(3), VAPCLP(3)
      VA(1)=X1-XI
      VA(2)=Y1-YI
      VA(3)=Z1-ZI
      VL(1)=X2-X1
      VL(2)=Y2-Y1
      VL(3)=Z2-Z1
      VAP(1)=VA(1)
      VAP(2)=BETA*VA(2)
      VAP(3)=BETA*VA(3)
      VBP(1)=X2-XI
      VBP(2)=BETA*(Y2-YI)
      VBP(3)=BETA*(Z2-ZI)
      VLP(1)=VL(1)
      VLP(2)=BETA*VL(2)
      VLP(3)=BETA*VL(3)
      CALL CRSPRD (VA,VL,VACL)
      CALL CRSPRD (VAP,VLP,VAPCLP)
      CALL DOTPRD (VAPCLP,VAPCLP,DAPCLP)
      IF (ABS(DAPCLP).LT.(1.E-10)) GO TO 10
      CALL DOTPRD (VBP,VBP,DBP)
      BPMOD=SQRT(DBP)
      CALL DOTPRD (VAP,VAP,DAP)
      APMOD=SQRT(DAP)
      CALL DOTPRD (VBP,VLP,DBPLP)
      DBPLP=DBPLP/BPMOD
      CALL DOTPRD (VAP,VLP,DAPLP)
      DAPLP=DAPLP/APMOD
      CONST=(DBPLP-DAPLP)/DAPCLP
      GO TO 20
   10 CONST=0.
   20 CONTINUE
      VACL(1)=VACL(1)*CONST
      VACL(2)=VACL(2)*CONST
      VACL(3)=VACL(3)*CONST
```

```
      RETURN                                                  INF 410
      END                                                     INF 420-
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      SUBROUTINE NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CO
     1NI,CONJ,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,CPCW1,XCP,YCP,
     2GAMA,YYM)
C     EVALUATES TOTAL VELOCITY AT POINT (XEE,YEE,ZEE)
      COMMON /ALLRA/ AA(17),SINA,COSA,AB(5),BSQD4P
      COMMON /GM/ ITER,L1,L2,L3,L4,L5,L6,L7,L8
      DIMENSION DUMMY(1), CONI(1), CONJ(1), CONK(1), CI(1), CJ(1), CK(1)
     1, C(1), THETP(1), XTE(1), XLE(1), YLE(1), CONS(1), SI(1), CPCW1(1)
     2, XCP(1), YCP(1), GAMA(1), YYM(1), XN(NWNG,2), YN(NWNG,2), NP(4),
     3U(4,3), V(3)
C     IF POINT IS IN THE WING PLANE, THE REGULAR METHOD FOR VELOCITY
C     EVALUATION IS USED.
      IF (ZEE.LE.0.00001) GO TO 110
      IF (YEE.GT.YYM(NSW1)) GO TO 110
      CH1=XTE(1)-XLE(1)
      CH2=XTE(2)-XLE(2)
      XLY=XLE(1)+(YEE-YLE(1))*(XLE(2)-XLE(1))/(YLE(2)-YLE(1))
      CHY=CH1+(YEE-YLE(1))*(CH2-CH1)/(YLE(2)-YLE(1))
      XC=(XEE-XLY)/CHY
      IF (XC.LT.0.0.OR.XC.GT.1.0) GO TO 110
      ZC=ZEE/CHY
C     IF THE POINT (XEE,YEE,ZEE) IS AT Z/C(LOCAL) LESS THAN ZTOL, THE
C     VELOCITY IS OBTAINED BY LINEAR INTERPOLATION OF THE VELOCITIES
C     CALCULATED ABOVE FOUR WING CONTROL POINTS AMONG WHICH THE POINT IS
C     LOCATED. BY NUMERICAL EXPERIMENTATION ZTOL HAS BEEN OBTAINED TO BE
C     0.2.
      ZTOL=0.2
      IF (ZC.GE.ZTOL) GO TO 110
      I=1
      IF (YEE.LE.YYM(I)) GO TO 20
   10 IF (YEE.GT.YYM(I).AND.YEE.LE.YYM(I+1)) GO TO 20
      I=I+1
      IF (I.LT.NSW1) GO TO 10
   20 J=1
      IF (XC.LE.CPCW1(1)) GO TO 50
   30 IF (XC.GT.CPCW1(J).AND.XC.LE.CPCW1(J+1)) GO TO 40
      J=J+1
      IF (J.LT.NCW) GO TO 30
   40 NP(1)=(I-1)*NCW+J
      NP(2)=NP(1)+1
```

```
      NP(3)=NP(1)+NCW
      NP(4)=NP(3)+1
      XC1=CPCW1(J)
      XC2=CPCW1(J+1)
      GO TO 60
50    NP(1)=NCW*NSW1+I
      NP(2)=(I-1)*NCW+1
      NP(3)=NP(1)+1
      NP(4)=NP(2)+NCW
      XC1=0.
      XC2=CPCW1(1)
60    CONTINUE
C     EVALUATION OF INDUCED VELOCITY AT FOUR POINTS
      DO 80 I=1,4
      NN=NP(I)
      CALL VOTWNG (C,THETP,XCP(NN),YCP(NN),ZEE,XN,YN,XTE,YLE,CONS,DUMMY(
     1L1),DUMMY(L2),DUMMY(L3),DUMMY(L4),DUMMY(L5),DUMMY(L6),DUMMY(L7),DU
     2MMY(L9),CONI,CONJ,CONK,SI,NSW1,NCW,NWNG)
      U(I,1)=0.
      U(I,2)=0.
      U(I,3)=0.
      DO 70 J=1,NWNG
      U(I,1)=U(I,1)+CONI(J)*GAMA(J)
      U(I,2)=U(I,2)+CONJ(J)*GAMA(J)
70    U(I,3)=U(I,3)+CONK(J)*GAMA(J)
80    CONTINUE
C     INTERPOLATION
      NN1=NP(1)
      NN2=NP(3)
      Y1=YCP(NN1)
      Y2=YCP(NN2)
      DO 90 I=1,3
      UA=U(1,I)+(U(3,I)-U(1,I))*(YEE-Y1)/(Y2-Y1)
      UB=U(2,I)+(U(4,I)-U(2,I))*(YEE-Y1)/(Y2-Y1)
90    V(I)=UA+(UB-UA)*(XC-XC1)/(XC2-XC1)
      UU=V(1)+COSA
      VV=V(2)
      WW=V(3)+SINA
      CALL VOTFRE (XEE,YEE,ZEE,CI,CJ,CK,NSW1,B ?D4P,XLE,YLE)
```

```
C     FINAL TOTAL VELOCITY                                              VEL 800
      DO 100 J=1,NSW1                                                   VEL 810
      JJ=NWNG+J                                                         VEL 820
      UU=UU+CI(J)*GAMA(JJ)                                              VEL 830
      VV=VV+CJ(J)*GAMA(JJ)                                              VEL 840
  100 WW=WW+CK(J)*GAMA(JJ)                                              VEL 850
      RETURN                                                            VEL 860
C     EVALUATION OF VELOCITY WHEN POINT IS IN THE WING PLANE            VEL 870
  110 CONTINUE                                                          VEL 880
      CALL VOTWNG (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY(L1),DUMMVEL 890
     1Y(L2),DUMMY(L3),DUMMY(L4),DUMMY(L5),DUMMY(L6),DUMMY(L7),DUMMY(L8),VEL 900
     2CONI,CONJ,CONK,ST,NSW1,NCW,NWNG)                                  VEL 910
      CALL VOTFRE (XEE,YEE,ZEE,CI,CJ,CK,NSW1,BSOD4P,XLE,YLE)            VEL 920
C     FREE STREAM VELOCITY                                              VEL 930
      UU=COSA                                                           VEL 940
      VV=0.                                                             VEL 950
      WW=SINA                                                           VEL 960
C     VELOCITY DUE TO FREE ELEMENTS                                     VEL 970
      DO 120 I=1,NSW1                                                   VEL 980
      NO=NWNG+I                                                         VEL 990
      UU=UU+CI(I)*GAMA(NO)                                              VEL1000
      VV=VV+CJ(I)*GAMA(NO)                                              VEL1010
  120 WW=WW+CK(I)*GAMA(NO)                                              VEL1020
C     VELOCITY DUE TO WING                                              VEL1030
      DO 130 I=1,NSW1                                                   VEL1040
      DO 130 J=1,NCW                                                    VEL1050
      NO=(I-1)*NCW+J                                                    VEL1060
      UU=UU+CONI(NO)*GAMA(NO)                                           VEL1070
      VV=VV+CONJ(NO)*GAMA(NO)                                           VEL1080
  130 WW=WW+CONK(NO)*GAMA(NO)                                           VEL1090
      RETURN                                                            VEL1100
      END                                                               VEL1110-
```

```
      OVERLAY (LEVSP,1,0)
      PROGRAM GEOM
C     DEFINES THE WING AND FREE ELEMENT GEOMETRY
C     MAXIMUM VALUES
C     ** NCW. = 9
C     ** NNCW = NCW+1 = 10
C     ** NSW = 20
C     ** NSW1 = NSW-1 = 19
C     ** NWNG = NNCW*NSW1 = 190
C     ** NCPTTL = (NNCW+1)*NSW1 = 209
      COMMON XXL(2),XXT(2),YL(2),CPCWL(10),CPCW1(10),SI(10),SN(10),SNN(1
     10),SWP(10),SLOPE(10),XL(2,10),C(19),THETP(19),CONS(19),CPSW1(19),X
     2LM(19),XTM(19),YLM(19),CTT(19),CPSWL(20),XLE(20),XTE(20),YLE(20),X
     3AVWNG(190),YAVWNG(190),XN(190,2),YN(190,2),XCP(209),YCP(209),X(10,
     420),Y(10,20)
      COMMON /ALLI/ NSW,NSW1,NCW,NWNG,NCPTTL,MITER,IPUNCH
      COMMON /ALLRA/ TTL(16),ALPHA,SINA,COSA,SWPLE,BETA,BETA2,TANPH1,B2P
     1H1,BSQD4P,D4,CON,PI,D4SQ2,CBAR,HALFB,AREA
      COMMON /XSTN/ XBRR(25),NBRR
      THEND=5HEND
C     ******************************************************************
      READ (5,130) TTL
      IF (TTL(1).EQ.THEND) GO TO 120
      READ (5,160) NCW,NSW,NBRR,NCONTS,MITER,IPUNCH
      NSW1=NSW-1
      READ (5,150) (XXL(I),XXT(I),YL(I),I=1,2)
      READ (5,150) ALPHA,AMACH,DELTA,DL,XEND,CBAR,AREA
      READ (5,150) (XBRR(I),I=1,NBRR)
      READ (5,150) (CTT(I),I=1,NSW1)
C     ******************************************************************
      WRITE (6,170) TTL
      WRITE (6,160) NCW,NSW,NBRR,NCONTS,MITER,IPUNCH
      WRITE (6,150) (XXL(I),XXT(I),YL(I),I=1,2)
      WRITE (6,150) ALPHA,AMACH,DELTA,DL,XEND,CBAR,AREA
      WRITE (6,150) (XBRR(I),I=1,NBRR)
      WRITE (6,150) (CTT(I),I=1,NSW1)
      NNCW=NCW
      NCW=NNCW+1
C     NPRCY=0, USED FOR BOUND ELEMENTS = (NCW+1)
C     NPRCY=1, USED FOR BOUND ELEMENTS = NCW
```

```
      NPRCY=0
   10 IF (NPRCY.EQ.1) NCW=NNCW
      PI=3.14159265
      FN2=2*NCW
      PIJ=PI/FLOAT(NCW)
      TWOPI=2.*PI
      DO 20 I=1,NCW
      CPCWL(I)=50.*(1.-COS((2.*FLOAT(I)-1.)*PI/FN2))
      CPCW1(I)=50.*(1.-COS(FLOAT(I)*PI/FLOAT(NCW)))
      CC=CPCWL(I)/100.
      SNN(I)=2.*SQRT(CC*(1.-CC))
      PSIJ=(2.*FLOAT(I)-1.)*PIJ/2.
      SN(I)=SIN(PSIJ)/TWOPI
   20 SI(I)=TWOPI*SN(I)
      SWPLE=ATAN((XXL(2)-XXL(1))/(YL(2)-YL(1)))
      FM2=2*NSW
      DO 30 J=1,NSW
   30 CPSWL(J)=50.*(1.-COS((2.*FLOAT(J)-1.)*PI/FM2))
      CPSWL(1)=0.
      DO 40 I=1,NSW1
   40 CPSW1(I)=50.*(1.-COS(FLOAT(I)*PI/FLOAT(NSW)))
      CALL PNLWNG (NSW,NWNG,NCW)
      HALFB=YL(2)
      DO 50 I=1,NSW1
      C(I)=XTM(I)-XLM(I)
      YYLM=YLM(I)/HALFB
   50 THETP(I)=ARCOS(YYLM)
      NCPTTL=NSW1+NWNG
      IF (NPRCY.EQ.1) GO TO 60
      NCW1=NCW
C     ..................................................................
      REWIND 1
      REWIND 7
      WRITE (1) NCW,NWNG
      WRITE (1) (SI(I),SNN(I),SWP(I),I=1,NCW)
      WRITE (1) (XAVWNG(I),YAVWNG(I),I=1,NWNG,NCW)
C     ..................................................................
      NPRCY=1
      GO TO 10
```

```
60    DO 70 I=1,NCW
      CPCWL(I)=CPCWL(I)/100.
70    CPCW1(I)=CPCW1(I)/100.
      DO 80 I=1,NSW
80    CPSWL(I)=CPSWL(I)/100.
      DO 90 I=1,NSW1
90    CPSW1(I)=CPSW1(I)/100.
C     EVALUATING THE CONSTANTS
      ALPHA=ALPHA*PI/180.
      TANPH1=TAN(ALPHA)
      TANPH2=TANPH1*TANPH1
      BETA2=1.-AMACH*AMACH
      BETA=SQRT(BETA2)
      B2PH1=BETA2*TANPH1
      D4=BETA2*TANPH2+1.
      D4SQ2=2.*SQRT(D4)
      CON=BETA2/(8.*FLOAT(NCW))
      BSQD4P=BETA2/(4.*PI)
      CON1=COS(SWPLE)
      CON2=(SIN(SWPLE))/CON1
      CON3=FLOAT(NCW)*SQRT(BETA2+CON2*CON2)
      CON4=2.*CON1/(PI*SQRT(1.-AMACH*AMACH*CON1*CON1))
      DO 100 I=1,NSW1
100   CTT(I)=CON3*SQRT(CON4*CTT(I))
      DO 110 I=1,NSW1
110   CONS(I)=CON*C(I)
      SINA=SIN(ALPHA)
      COSA=COS(ALPHA)
C     ..................................................................
      WRITE (1) (SNN(I),SWP(I),I=1,NCW)
      WRITE (1) (XAVWNG(I),YAVWNG(I),I=1,NWNG)
      WRITE (1) (C(I),I=1,NSW1)
      WRITE (1) (THETP(I),I=1,NSW1)
      WRITE (1) (XTE(I),XLE(I),YLE(I),I=1,NSW)
      WRITE (1) (XLM(I),YLM(I),I=1,NSW1)
      WRITE (1) (CONS(I),I=1,NSW1)
      WRITE (1) (SI(I),SN(I),I=1,NCW)
      WRITE (1) (XCP(I),YCP(I),I=1,NCPTTL)
      WRITE (1) ((XN(I,J),YN(I,J),J=1,2),I=1,NWNG)
```

```
      WRITE (1) (CTT(I),I=1,NSW1)                                       GE01190
      WRITE (1) (CPCWL(I),I=1,NCW)                                      GE01200
      WRITE (1) (CPCW1(I),I=1,NCW)                                      GE01210
      WRITE (1) (CPSWL(I),I=1,NSW)                                      GE01220
      WRITE (1) (CPSW1(I),I=1,NSW1)                                     GE01230
C     ..................................................................GE01240
      CALL FRELM (XXL,XXT,YL,XLE,XTE,YLE,PI,NCW1,NSW1,XEND,DELTA,ALPHA,DGE01250
     1L,NCONTS)                                                         GE01260
      RETURN                                                            GE01270
120   WRITE (6,140)                                                     GE01280
      STOP                                                              GE01290
C                                                                       GE01300
130   FORMAT (16A5)                                                     GE01310
140   FORMAT (1H1,/,10X,19HALL CASES COMPLETED)                         GE01320
150   FORMAT (8F10.5)                                                   GE01330
160   FORMAT (10I5)                                                     GE01340
170   FORMAT (1H1,/,17H INPUT DATA CARDS/,16A5)                         GE01350
      END                                                               GE01360-
```

```
      SUBROUTINE PNLWNG (NSW,LPANEL,NCW)
C     GENERATES THE GRID OF BOUND AND TRAILING VORTEX ELEMENTS
      COMMON XXL(2),XXT(2),YL(2),CPCWL(10),CPCW1(10),SI(10),SN(10),SNN(1
     10),SWP(10),SLOPE(10),XL(2,10),C(19),THETP(19),CONS(19),CPSW1(19),X
     2LM(19),XTM(19),YLM(19),CTT(19),CPSWL(20),XLE(20),XTE(20),YLE(20),X
     3AVWNG(190),YAVWNG(190),XN(190,2),YN(190,2),XCP(209),YCP(209),X(10,
     420),Y(10,20)
      DO 10 I=1,2
      D=XXT(I)-XXL(I)
      DO 10 J=1,NCW
   10 XL(I,J)=XXL(I)+CPCWL(J)*D/100.
      SPAN=YL(2)-YL(1)
      DO 20 I=1,NCW
      SLOPE(I)=(XL(2,I)-XL(1,I))/SPAN
   20 SWP(I)=ATAN(SLOPE(I))
      DO 30 K=1,NSW
      YK=CPSWL(K)*SPAN/100.
      YL1=YL(1)+YK
      DO 30 J=1,NCW
      Y(J,K)=YL1
   30 X(J,K)=XL(1,J)+SLOPE(J)*YK
      NSW1=NSW-1
      XLE(1)=XXL(1)
      XTE(1)=XXT(1)
      YLE(1)=Y(1,1)
      DLE=(XXL(2)-XXL(1))/SPAN
      DTE=(XXT(2)-XXT(1))/SPAN
      DO 40 I=2,NSW
      YLE(I)=Y(1,I)
      YLM(I-1)=YLE(1)+CPSW1(I-1)*SPAN/100.
      DLEL=DLE*(Y(1,I)-Y(1,I-1))
      DTET=DTE*(Y(1,I)-Y(1,I-1))
      XLE(I)=XLE(I-1)+DLEL
      XTE(I)=XTE(I-1)+DTET
      XLM(I-1)=XLE(1)+SPAN*CPSW1(I-1)*DLE/100.
   40 XTM(I-1)=XTE(1)+SPAN*CPSW1(I-1)*DTE/100.
      DO 60 K=1,NSW1
      NP=(K-1)*NCW
      CC=XTM(K)-XLM(K)
      DO 60 J=1,NCW
```

```
      NPANEL=NP+J                                                       PNL 410
      XCP(NPANEL)=XLM(K)+CC*CPCW1(J)/100.                               PNL 420
      YCP(NPANEL)=YLM(K)                                                PNL 430
      XAVWNG(NPANEL)=XLM(K)+CC*CPCWL(J)/100.                            PNL 440
      YAVWNG(NPANEL)=YLM(K)                                             PNL 450
      DO 50 I=1,2                                                       PNL 460
      KI=K+I-1                                                          PNL 470
      XN(NPANEL,I)=X(J,KI)                                              PNL 480
50    YN(NPANEL,I)=Y(J,KI)                                              PNL 490
60    CONTINUE                                                          PNL 500
      LPANEL=NPANEL                                                     PNL 510
      DO 70 K=1,NSW1                                                    PNL 520
      NP=LPANEL+K                                                       PNL 530
      XCP(NP)=XLM(K)                                                    PNL 540
70    YCP(NP)=YLM(K)                                                    PNL 550
      RETURN                                                            PNL 560
      END                                                               PNL 570
```

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```
      SUBROUTINE FRELM (XXL,XXT,YL,XLE,XTE,YLE,PI,NCW1,NSW1,XEND,DELTA,AFLM  10
     1LPHA,DL,NCONTS)                                                   FLM  20
C     FINDS THE INETIAL COORDINATES OF FREE VORTEX ELEMENTS             FLM  30
      COMMON /ALLRB/ XE(40),YE(40),ZE(40),XXE(30),YYE(30),ZZE(30),ZMIN,NFLM  40
     1ELM(11),NNELM(12)                                                 FLM  50
      COMMON /XPLOT/ XMN,YMN,ZMN,XMX,YMX,ZMX                            FLM  60
      DIMENSION XXL(1), XXT(1), YL(1), XLE(1), XTE(1), YLE(1)           FLM  70
      AHPI=ALPHA                                                        FLM  80
      ALP=ALPHA*180./PI                                                 FLM  90
      IF (ALP.LE.15.) AHPI=(22.5-0.5*ALP)*PI/180.                       FLM 100
      NSW=NSW1+1                                                        FLM 110
      THT1=PI/(FLOAT(2*NCW1))                                           FLM 120
      CPC=0.5*(1.-COS(THT1))                                            FLM 130
      ZMIN=(XTE(1)-XLE(1))*TAN(AHPI)/10.                                FLM 140
      SAHPI=SIN(AHPI)                                                   FLM 150
      CAHPI=COS(AHPI)                                                   FLM 160
      REWIND 2                                                          FLM 170
      REWIND 4                                                          FLM 180
C     EVALUATION OF COORDINATES OF LEADING-EDGE ELEMENTS                FLM 190
      DO 30 I=1,NSW1                                                    FLM 200
      XE(1)=XTE(I+1)                                                    FLM 210
      YE(1)=YLE(I+1)                                                    FLM 220
      ZE(1)=0.                                                          FLM 230
      XE(2)=XLE(I+1)+CPC*(XTE(I+1)-XLE(I+1))                            FLM 240
      YE(2)=YLE(I+1)                                                    FLM 250
      ZE(2)=0.                                                          FLM 260
      XE(3)=XLE(I)+CPC*(XTE(I)-XLE(I))                                  FLM 270
      YE(3)=YLE(I)                                                      FLM 280
      ZE(3)=0.                                                          FLM 290
      XE(4)=XLE(I)                                                      FLM 300
      YE(4)=YLE(I)                                                      FLM 310
      ZE(4)=0.                                                          FLM 320
      XE(5)=XLE(I)-0.05*(XTE(I)-XLE(I))                                 FLM 330
      IF (I.EQ.1) XMN=XE(5)                                             FLM 340
      YE(5)=YLE(I)                                                      FLM 350
      ZE(5)=0.                                                          FLM 360
      XE(6)=XE(4)+0.05*(XTE(I)-XLE(I))                                  FLM 370
      YE(6)=YE(4)                                                       FLM 380
      ZE(6)=ZMIN                                                        FLM 390
      J=6                                                               FLM 400
```

```
      XE(7)=XE(6)+DELTA*CAHPI
      YE(7)=YE(6)
      ZE(7)=ZE(6)+DELTA*SAHPI
      IF (I.EQ.1) GO TO 20
      J=7
10    XE(J+1)=XE(J)+DELTA
      YE(J+1)=YE(J)
      ZE(J+1)=ZE(J)
      IF (XE(J+1).GE.XEND) GO TO 20
      J=J+1
      GO TO 10
20    NELM(I)=J+1
      K=NELM(I)
C     ...................................................................
      IF (NCONTS.NE.0) WRITE (2) (XE(J),YE(J),ZE(J),J=1,5)
30    WRITE (4) K,(XE(J),YE(J),ZE(J),J=1,K)
C     ...................................................................
      NMAX=0
      DO 40 I=1,NSW1
40    IF (NMAX.LT.NELM(I)) NMAX=NELM(I)
C     EVALUATION OF COORDINATES OF WAKE ELEMENTS
      DO 70 I=1,NSW
      XXE(1)=XTE(I)
      YYE(1)=YLE(I)
      ZZE(1)=0.
      XXE(2)=XXE(1)+(XXT(1)-XXL(1))/10.
      YYE(2)=YYE(1)
      ZZE(2)=ZZE(1)
      XXE(3)=XXE(2)+(XXT(1)-XXL(1))/10.
      YYE(3)=YYE(2)
      ZZE(3)=ZZE(2)
      J=3
50    IF (XXE(J).GE.XEND) GO TO 60
      XXE(J+1)=XXE(J)+DL
      YYE(J+1)=YYE(J)
      ZZE(J+1)=ZZE(J)
      J=J+1
      GO TO 50
60    NNELM(I)=J
```

```
      K=J
C     ...................................................................
      IF (NCONTS.NE.0) WRITE (2) (XXE(J),YYE(J),ZZE(J),J=1,2)
70    WRITE (4) K,(XXE(J),YYE(J),ZZE(J),J=1,K)
C     ...................................................................
      NNMAX=0
      DO 80 I=1,NSW1
80    IF (NNMAX.LT.NNELM(I)) NNMAX=NNELM(I)
C     ...................................................................
      WRITE (4) NMAX,NNMAX,ZMIN,NCONTS
C     ...................................................................
      XLNT=XEND-XMN
      XMX=XEND
      XMX=XEND+0.20*XLNT
      YMN=0.
      YMX=YL(2)
      ZMN=-YL(2)/4.
      ZMX=YL(2)/2.
      IF (NCONTS.EQ.0) GO TO 130
C     READS LOCATION OF LEADING-EDGE ELEMENTS FROM INPUT DATA CARDS
C     *******************************************************************
      REWIND 2
      REWIND 4
      READ (5,160) (NELM(I),I=1,NSW1)
      DO 90 I=1,NSW1
      K=NELM(I)
      READ (5,150) ((X1,J=1,5),(XE(J),J=6,K))
      READ (5,150) ((Y1,J=1,5),(YE(J),J=6,K))
      READ (5,150) ((Z1,J=1,5),(ZE(J),J=6,K))
      READ (2) (XE(J),YE(J),ZE(J),J=1,5)
90    WRITE (4) K,(XE(J),YE(J),ZE(J),J=1,K)
C     READS LOCATION OF WAKE ELEMENTS FROM INPUT DATA CARDS
      READ (5,160) (NNELM(I),I=1,NSW)
      DO 100 I=1,NSW
      K=NNELM(I)
      READ (5,150) ((X1,J=1,2),(XXE(J),J=3,K))
      READ (5,150) ((Y1,J=1,2),(YYE(J),J=3,K))
      READ (5,150) ((Z1,J=1,2),(ZZE(J),J=3,K))
      READ (2) (XXE(J),YYE(J),ZZE(J),J=1,2)
```

```
100   WRITE (4) K,(XXE(J),YYE(J),ZZE(J),J=1,K)                    FLM1190
      WRITE (4) NMAX,NNMAX,ZMIN,NCONTS                            FLM1200
      REWIND 4                                                    FLM1210
      WRITE (6,160) (NELM(I),I=1,NSW1)                            FLM1220
      DO 110 I=1,NSW1                                             FLM1230
      READ (4) K,(XE(J),YE(J),ZE(J),J=1,K)                        FLM1240
      WRITE (6,140) (XE(J),J=1,K)                                 FLM1250
      WRITE (6,140) (YE(J),J=1,K)                                 FLM1260
110   WRITE (6,140) (ZE(J),J=1,K)                                 FLM1270
      WRITE (6,160) (NNELM(I),I=1,NSW)                            FLM1280
      DO 120 I=1,NSW                                              FLM1290
      READ (4) K,(XXE(J),YYE(J),ZZE(J),J=1,K)                     FLM1300
      WRITE (6,140) (XXE(J),J=1,K)                                FLM1310
      WRITE (6,140) (YYE(J),J=1,K)                                FLM1320
120   WRITE (6,140) (ZZE(J),J=1,K)                                FLM1330
130   WRITE (6,170)                                               FLM1340
C     ******************************************************************FLM1350
      RETURN                                                      FLM1360
C                                                                 FLM1370
140   FORMAT (14F9.4)                                             FLM1380
150   FORMAT (10F8.4)                                             FLM1390
160   FORMAT (10I2)                                               FLM1400
170   FORMAT (18H END OF INPUT DATA,//)                           FLM1410
      END                                                         FLM1420
```

```
      OVERLAY (LEVSP,2,0)                                              PLT  10
      PROGRAM PLOT                                                     PLT  20
C     SETS UP DIMENSIONS FOR PLOTTING LEADING-EDGE AND WAKE ELEMENTS   PLT  30
      COMMON D(1)                                                      PLT  40
      COMMON /ALLI/ NSW,NSW1                                           PLT  50
C     *****************************************************************PLT  60
      REWIND 4                                                         PLT  70
      NN=NSW1+NSW                                                      PLT  80
      CALL SKIPR (4,NN)                                                PLT  90
      READ (4) NMAX,NNMAX,ZMIN,NCONTS                                  PLT 100
C     *****************************************************************PLT 110
      MXE=1                                                            PLT 120
      MYE=MXE+NSW1*NMAX                                                PLT 130
      MZE=MYE+NSW1*NMAX                                                PLT 140
      MNELM=MZE+NSW1*NMAX                                              PLT 150
      MNEXT=MNELM+NSW1                                                 PLT 160
C     MNEXT=3*NSW*NMAX-3*NMAX+NSW                                      PLT 170
      CALL PLOTT (D(MXE),D(MYE),D(MZE),D(MNELM),NSW1)                  PLT 180
      MXXE=1                                                           PLT 190
      MYYE=MXXE+NSW*(NNMAX+2)                                          PLT 200
      MZZE=MYYE+NSW*(NNMAX+2)                                          PLT 210
      MNNELM=MZZE+NSW*(NNMAX+2)                                        PLT 220
      MNNEXT=MNNELM+NSW                                                PLT 230
C     MNNEXT=3*NSW*(NNMAX+2)+NSW+1                                     PLT 240
      CALL PLOTT (D(MXXE),D(MYYE),D(MZZE),D(MNNELM),NSW)               PLT 250
      RETURN                                                           PLT 260
      END                                                              PLT 270
```

```
      SUBROUTINE PLOTT (XE,YE,ZE,NNM,NS)                                PTT  10
C     MANIPULATES LEADING-EDGE AND WAKE ELEMENTS COORDINATES IN A FORM  PTT  20
C     SUITABLE FOR PLOTTING                                             PTT  30
      COMMON /ALLI/ NSW,NSW1                                            PTT  40
      COMMON /XPLOT/ XMN,YMN,ZMN,XMX,YMX,ZMX                            PTT  50
      DIMENSION NNM(1), XE(NS,1), YE(NS,1), ZE(NS,1), LABY(14), LABZ(14)PTT  60
      DATA LABY/6*6H      ,6HX VS Y,6*6H      ,2H  /                    PTT  70
      DATA LABZ/6*6H      ,6HX VS Z,6*6H      ,2H  /                    PTT  80
C     ******************************************************************PTT  90
      REWIND 4                                                          PTT 100
      IF (NS.EQ.NSW) GO TO 20                                           PTT 110
      DO 10 I=1,NSW1                                                    PTT 120
      READ (4) KK,(XE(I,J),YE(I,J),ZE(I,J),J=1,KK)                      PTT 130
10    NNM(I)=KK                                                         PTT 140
      NC=4                                                              PTT 150
      LABY(8)=6H(LEADI                                                  PTT 160
      LABY(9)=6HNG-EDG                                                  PTT 170
      LABY(10)=6HE ELEM                                                 PTT 180
      LABY(11)=6HENTS)                                                  PTT 190
      LABZ(8)=6H(LEADI                                                  PTT 200
      LABZ(9)=6HNG-EDG                                                  PTT 210
      LABZ(10)=6HE ELEM                                                 PTT 220
      LABZ(11)=6HENTS)                                                  PTT 230
      GO TO 50                                                          PTT 240
20    DO 30 I=1,NSW1                                                    PTT 250
30    READ (4)                                                          PTT 260
      DO 40 I=1,NSW                                                     PTT 270
      READ (4) KK,(XE(I,J),YE(I,J),ZE(I,J),J=1,KK)                      PTT 280
40    NNM(I)=KK                                                         PTT 290
      LABY(8)=6H(WAKE                                                   PTT 300
      LABY(9)=6HELEMEN                                                  PTT 310
      LABY(10)=6HTS)                                                    PTT 320
      LABY(11)=6H                                                       PTT 330
      LABZ(8)=6H(WAKE                                                   PTT 340
      LABZ(9)=6HELEMEN                                                  PTT 350
      LABZ(10)=6HTS)                                                    PTT 360
      LABZ(11)=6H                                                       PTT 370
C     ******************************************************************PTT 380
      NC=0                                                              PTT 390
50    DO 70 L=2,NS                                                      PTT 400
```

```
      I=L-1                                                             PTT 410
      K=NNM(L)-NC                                                       PTT 420
      DO 60 J=1,K                                                       PTT 430
      KK=J+NC                                                           PTT 440
      XE(I,J)=XE(L,KK)                                                  PTT 450
      YE(I,J)=YE(L,KK)                                                  PTT 460
   60 ZE(I,J)=ZE(L,KK)                                                  PTT 470
      XE(I,K+1)=XMN                                                     PTT 480
      YE(I,K+1)=YMN                                                     PTT 490
      ZE(I,K+1)=ZMN                                                     PTT 500
      XE(I,K+2)=XMX                                                     PTT 510
      YE(I,K+2)=YMX                                                     PTT 520
      ZE(I,K+2)=ZMX                                                     PTT 530
   70 NNM(I)=K+2                                                        PTT 540
      NS1=NS-1                                                          PTT 550
      CALL LNPLOT (XE,YE,NNM,NS1,NS,LABY)                               PTT 560
      CALL LNPLOT (XE,ZE,NNM,NS1,NS,LABZ)                               PTT 570
      RETURN                                                            PTT 580
      END                                                               PTT 590
```

```
      SUBROUTINE LNPLOT (X,Y,NELM,M,MMAX,LABEL)
C     GENERATES PLOT ON LINE PRINTER (WRITTEN BY KU COMPUTATION CENTER)
      DIMENSION NELM(MMAX), X(MMAX,1), Y(MMAX,1), ALINE(101), YAXIS(101)
     1, SYM(20), LABEL(1)
      DATA SYM/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H0,1HA,1HB,1HC,1HD,1
     1HE,1HF,1HG,1HH,1HI,1HJ/
      DATA YAXIS/1HI,9*1H-,1HI,9*1H-,1HI,9*1H-,1HI,9*1H-,1HI,9*1H-,1HI,9
     1*1H-,1HI,9*1H-,1HI,9*1H-,1HI,9*1H-,1HI,9*1H-,1HI/
      DATA BLANK,UP,PLUS/1H ,1HI,1H+/
      XMAX=X(1,1)
      XMIN=X(1,1)
      YMAX=Y(1,1)
      YMIN=Y(1,1)
      DO 10 I=1,M
      N=NELM(I)
      DO 10 J=1,N
      IF (X(I,J).GT.XMAX) XMAX=X(I,J)
      IF (X(I,J).LT.XMIN) XMIN=X(I,J)
      IF (Y(I,J).GT.YMAX) YMAX=Y(I,J)
      IF (Y(I,J).LT.YMIN) YMIN=Y(I,J)
   10 CONTINUE
      KEY=1
      ZMAX=XMAX
      ZMIN=XMIN
   20 RANGE=ZMAX-ZMIN
      IF (RANGE.EQ.0.0) RANGE=ZMAX/2.
      SCALE=1.0E-9
   30 SCALE=10.*SCALE
      IF (SCALE.LT.RANGE) GO TO 30
      ZMIN=ZMIN/SCALE
      ZMAX=ZMAX/SCALE
      MIN=20.*(ZMIN-0.025)
      MAX=20.0*(ZMAX+0.025)
      BOTTOM=0.05*FLOAT(MIN)
      TOP=0.05*FLOAT(MAX)
      RANGE=0.1*(TOP-BOTTOM)
      IF (RANGE.EQ.0.0) RANGE=0.1*(TOP/2.)
   40 IF (BOTTOM.LE.ZMIN) GO TO 50
      BOTTOM=BOTTOM-RANGE
      GO TO 40
```


C-2

```
50    IF (TOP.GE.ZMAX) GO TO 60
      TOP=TOP+RANGE
      GO TO 50
60    CONTINUE
      IF (KEY.EQ.2) GO TO 70
      KEY=2
      ZMAX=YMAX
      ZMIN=YMIN
      YINC=0.01*(TOP-BOTTOM)
      XINC=YINC*SCALE
      XBOT=BOTTOM*SCALE
      GO TO 20
70    CONTINUE
      YINC=0.0125*(TOP-BOTTOM)
      YLOW=TOP+YINC
      YINC=2.*YINC
      WRITE (6,160)
      KEY=5
80    CONTINUE
      DO 90 IJ=2,101
90    ALINE(IJ)=BLANK
      YHIGH=YLOW
      YLOW=YHIGH-YINC
      YHS=SCALE*YHIGH
      YLS=SCALE*YLOW
      DO 110 I=1,M
      N=NELM(I)-2
      DO 110 J=1,N
      IF (Y(I,J).GT.YHS.OR.Y(I,J).LE.YLS) GO TO 110
      INDEX=(X(I,J)-XBOT)/XINC
      INDEX=INDEX+1
      IF (INDEX.GT.101) INDEX=101
      IF (ALINE(INDEX).NE.BLANK) GO TO 100
      ALINE(INDEX)=SYM(I)
      GO TO 110
100   ALINE(INDEX)=PLUS
110   CONTINUE
      ALINE(1)=UP
      IF (KEY.NE.5) GO TO 120
```

```
      TPP=TOP*SCALE                                                     LNP 800
      WRITE (6,170) TPP,ALINE                                           LNP 810
      GO TO 130                                                         LNP 820
  120 WRITE (6,180) ALINE                                               LNP 830
  130 CONTINUE                                                          LNP 840
      KEY=KEY-1                                                         LNP 850
      IF (KEY.EQ.0) KEY=5                                               LNP 860
      TOP=TOP-YINC                                                      LNP 870
      IF (TOP.GE.BOTTOM) GO TO 80                                       LNP 880
      IF (KEY.NE.4) GO TO 80                                            LNP 890
      WRITE (6,210) YAXIS                                               LNP 900
      XINC=10.0*XINC                                                    LNP 910
      ALINE(1)=XBOT                                                     LNP 920
      DO 140 I=2,11                                                     LNP 930
  140 ALINE(I)=ALINE(I-1)+XINC                                          LNP 940
      WRITE (6,190) (ALINE(I),I=1,11)                                   LNP 950
C                                                                       LNP 960
      WRITE (6,200) (LABEL(I),I=1,14)                                   LNP 970
  150 RETURN                                                            LNP 980
C                                                                       LNP 990
  160 FORMAT (1H1,/)                                                    LNP1000
  170 FORMAT (F10.3,1X,101A1)                                           LNP1010
  180 FORMAT (11X,101A1)                                                LNP1020
  190 FORMAT (5X,11F10.3)                                               LNP1030
  200 FORMAT (//,20X,13A6,A2)                                           LNP1040
  210 FORMAT (11X,101A1)                                                LNP1050
      END                                                               LNP1060-
```

```
      OVERLAY (LEVSP,3,0)
      PROGRAM SOLN
C     SETS UP DIMENSIONS FOR SOLVING THE STRENGTHS OF WING AND LEADING-
C     EDGE VORTEX SYSTEM
      COMMON D(1)
      COMMON /ALLI/ NSW,NSW1,NCW,NWNG,NCPTTL
      LC=1
      LTHETP=LC+NSW1
      LXTE=LTHETP+NSW1
      LXLE=LXTE+NSW
      LYLE=LXLE+NSW
      LCONS=LYLE+NSW
      LCTT=LCONS+NSW1
      LCPWL=LCTT+NSW1
      LCPSW=LCPWL+NCW
      LSI=LCPSW+NSW1
      LSN=LSI+NCW
      LXCP=LSN+NCW
      LYCP=LXCP+NCPTTL
      LXN=LYCP+NCPTTL
      LYN=LXN+2*NWNG
      LCONI=LYN+2*NWNG
      LCONJ=LCONI+NWNG
      LCONK=LCONJ+NWNG
      LCI=LCONK+NWNG
      LCJ=LCI+NWNG
      LCK=LCJ+NWNG
      LDUMY=LCK+NWNG
      LNEXT=LDUMY+8*NWNG
C     LNEXT=20*NWNG+10*NSW+3*NCW-6
      MNEXT=LCJ+(NCPTTL+1)**2/4
C     MNEXT=(NCPTTL+1)**2/4+10*NWNG+10*NSW+3*NCW-6
      CALL AERODN (NWNG,D(LC),D(LTHETP),D(LXTE),D(LXLE),D(LYLE),D(LCONS)
     1,D(LSI),D(LSN),D(LXCP),D(LYCP),D(LXN),D(LYN),D(LCONI),D(LCONJ),D(L
     2CONK),D(LCI),D(LCJ),D(LCK),D(LDUMY),D(LCTT),D(LCPWL),D(LCPSW))
      RETURN
      END
```

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```
      SUBROUTINE AERODN (NWNG,C,THETP,XTE,XLE,YLE,CONS,SI,SN,XCP,YCP,XN,
     1YN,CONI,CONJ,CONK,CI,CJ,CK,DUMMY,CT,CPCWL,CPSW1)
C     SOLVES FOR THE STRENGTHS OF WING AND LEADING-EDGE VORTEX SYSTEM
      COMMON /ALLI/ NSW,NSW1,NCW,IWNG,NCPTTL
      COMMON /ALLRA/ AA(17),SINA,AB(6),BSQD4P
      COMMON /GM/ ITER,L1,L2,L3,L4,L5,L6,L7,L8
      COMMON /NCTT/ NCT,NCON
      DIMENSION C(1), THETP(1), XTE(1), XLE(1), YLE(1), CONS(1), SI(1),
     1SN(1), XCP(1), YCP(1), DUMMY(1), CONI(1), CONJ(1), CONK(1), CI(1),
     2 CJ(1), CK(1), CT(1), CPCWL(1), CPSW1(1), XN(NWNG,2), YN(NWNG,2)
C     ******************************************************************
      REWIND 1
      REWIND 2
      REWIND 3
      CALL SKIPR (1,5)
      READ (1) (C(I),I=1,NSW1)
      READ (1) (THETP(I),I=1,NSW1)
      READ (1) (XTE(I),XLE(I),YLE(I),I=1,NSW)
      CALL SKIPR (1,1)
      READ (1) (CONS(I),I=1,NSW1)
      READ (1) (SI(I),SN(I),I=1,NCW)
      READ (1) (XCP(I),YCP(I),I=1,NCPTTL)
      READ (1) ((XN(I,J),YN(I,J),J=1,2),I=1,NWNG)
      READ (1) (CT(I),I=1,NSW1)
      READ (1) (CPCWL(I),I=1,NCW)
      CALL SKIPR (1,2)
      READ (1) (CPSW1(I),I=1,NSW1)
C     ******************************************************************
C     INFLUENCE COEFFICIENT MATRIX EVALUATION
      L1=1
      L2=L1+NWNG
      L3=L2+NWNG
      L4=L3+NWNG
      L5=L4+NWNG
      L6=L5+NWNG
      L7=L6+NWNG
      L8=L7+NWNG
      NCON=0
      NCT=0
      DO 10 I=1,NCPTTL
```

```
      ZCP=0.
      CALL VDTWNG (C,THETP,XCP(I),YCP(I),ZCP,XN,YN,XTE,YLE,CONS,DUMMY(L1
     1),DUMMY(L2),DUMMY(L3),DUMMY(L4),DUMMY(L5),DUMMY(L6),DUMMY(L7),DUMM
     2Y(L8),CONI,CONJ,CONK,SI,NSW1,NCW,NWNG)
      WRITE (2) (CONK(J),J=1,NWNG)
      CALL VDTFRE (XCP(I),YCP(I),ZCP,CI,CJ,CK,NSW1,BSQD4P,XLE,YLE)
      WRITE (3) (CK(J),J=1,NSW1)
10    CONTINUE
C     GAMA-EVALUATION
      REWIND 2
      REWIND 3
      READ (2) (CONI(I),I=1,NWNG)
      NWNG1=NWNG+1
      NWNB=NWNG+NSW1
      NWNB1=NWNB+1
      READ (3) (CONI(I),I=NWNG1,NWNB)
      CONI(NWNB1)=SINA
      IJ=1
      DO 20 I=1,NWNB
20    CJ(I)=-CONI(I+1)/CONI(1)
      IJ=2
      NJ=NWNB-1
30    CONTINUE
      READ (2) (CONI(I),I=1,NWNG)
      READ (3) (CONI(I),I=NWNG1,NWNB)
      CONI(NWNB1)=SINA
      IF (IJ.GT.NWNG) CONI(NWNB1)=SINA+CT(IJ-NWNG)
      CALL VMSEQN (NJ,IJ,CONI,CJ,CONK)
      IJ=IJ+1
      NJ=NJ-1
      IF (IJ.LE.NWNB) GO TO 30
      WRITE (6,80)
      DO 40 I=1,NSW1
      DO 40 J=1,NCW
      NP=(I-1)*NCW+J
40    WRITE (6,90) CPCWL(J),CPSW(I),CJ(NP)
      WRITE (6,100)
      DO 50 I=1,NSW1
      J=NWNG+I
```

```
50    WRITE (6,90) CPSW1(I),CJ(J)
C     EVALUATION OF SECTIONAL LEADING-EDGE THRUST
      CALL THRST (CJ,CONI,CONJ)
      NERR=0
      DO 60 I=1,NSW1
60    IF (ABS(CONJ(I)-CT(I)).GE.(1.0E-10)) NERR=1
      IF (NERR.EQ.1) WRITE (6,110)
      GMSUM=0.
      DO 70 I=2,NSW1
      KS=NWNG+I
70    GMSUM=GMSUM+CJ(KS)
C     ..........................................................................
      REWIND 2
      WRITE (2) (CJ(I),I=1,NWNB)
      WRITE (7) GMSUM
C     ..........................................................................
      RETURN
C
80    FORMAT (1H1,//,22H WING VORTEX STRENGTHS,/,22H *********************
     1**,//,29H       X/C       2Y/3      GAMAY,/,29H       ***        ****
     2  *****)
90    FORMAT (3F10.5)
100   FORMAT (//,32H LEADING-EDGE VORTICES STRENGTHS,/,31H *************
     1*****************,//,20H     2Y/3     CAPGAMA,/,20H      ****      ***
     2****)
110   FORMAT (//,34H ERROR IN SECTIONAL CT CALCULATION,/,10F10.5)
      END
```

```
      SUBROUTINE VMSEQN (NC1,K,AA,A,CA)
C     SOLVES A SYSTEM OF SIMULTANEOUS EQUATIONS
      DIMENSION AA(1), CA(1), A(1)
      NC=K*NC1
      SUM1=0.
      K1=K-1
      JJ=1
      DO 10 J=1,K1
      SUM1=SUM1+AA(J)*A(JJ)
   10 JJ=JJ+NC1+1
      SUM1=SUM1+AA(K)
      DO 30 I=1,NC1
      SUM2=0.
      JJ=I+1
      DO 20 J=1,K1
      SUM2=SUM2+AA(J)*A(JJ)
   20 JJ=JJ+NC1+1
      KK=K+I
      SUM2=SUM2+AA(KK)
   30 CA(I)=-SUM2/SUM1
      M=1
      L=0
      KNC=(K-1)*NC1
      DO 60 I=1,NC
      IF (I.GT.KNC) GO TO 50
      MM=(M-1)*NC1+1
      IF (I.EQ.MM) GO TO 70
   40 KK=KK+1
      IL=I+L
      A(I)=CA(KK)*BASE+A(IL)
      GO TO 60
   50 II=I-KNC
      A(I)=CA(II)
   60 CONTINUE
      GO TO 80
   70 II=MM+M-1
      BASE=A(II)
      KK=0
      L=L+1
      M=M+1
```

```
      GO TO 40                                                          VMS 410
80    CONTINUE                                                          VMS 420
      RETURN                                                            VMS 430
      END                                                               VMS 440-
```

```
      SUBROUTINE THRST (SGM,CONK,CT)
C     EVALUATES SECTIONAL LEADING-EDGE THRUST COEFFICIENTS
      COMMON /ALLI/ NSW,NSW1,NCW,NWNG
      COMMON /ALLRA/ AA(17),SINA,COSA,SWPLE,A3,BETA2,AC(5),PI
      DIMENSION SGM(1), CONK(1), CT(1)
      AM2=1.-BETA2
      FCOS=COS(SWPLE)
      FTAN=TAN(SWPLE)
      VAR1=FLOAT(NCW)*SQRT(FTAN*FTAN+BETA2)
      VAR2=SQRT(1.-AM2*FCOS*FCOS)
      REWIND 2
      REWIND 3
      CALL SKIPR (2,NWNG)
      CALL SKIPR (3,NWNG)
      DO 30 I=1,NSW1
      WL=0.
      READ (2) (CONK(J),J=1,NWNG)
      DO 10 J=1,NWNG
10    WL=WL+CONK(J)*SGM(J)
      READ (3) (CONK(J),J=1,NSW1)
      DO 20 J=1,NSW1
      JJ=NWNG+J
20    WL=WL+CONK(J)*SGM(JJ)
      THRT1=(WL+SINA)/VAR1
30    CT(I)=(PI/2.)*VAR2*THRT1*THRT1/FCOS
      RETURN
      END
```

```
      OVERLAY (LEVSP,4,0)
      PROGRAM LOADS
C     SETS UP DIMENSIONS FOR EVALUATING AERODYNAMIC CHARACTERSTICS
      COMMON D(1)
      COMMON /ALLI/ NSW,NSW1,NCW,NWNG
      DIMENSION W(4100)
      NNCW=NCW+1
      NWNP=NNCW*NSW1
      LCI=1
      LCJ=LCI+NWNG
      LCK=LCJ+NWNG
      LCONI=LCK+NWNG
      LCONJ=LCONI+NWNG
      LCONK=LCONJ+NWNG
      LXVWNG=LCONK+NWNG
      LYVWNG=LXVWNG+NWNG
      LXLE=LYVWNG+NWNG
      LXTE=LXLE+NSW
      LYLE=LXTE+NSW
      LSI=LYLE+NSW
      LC=LSI+NCW
      LSWP=LC+NSW1
      LXN=LSWP+NCW
      LYN=LXN+2*NWNG
      LSNN=LYN+2*NWNG
      LTHETP=LSNN+NCW
      LCONS=LTHETP+NSW1
      LDUMMY=LCONS+NSW1
      LCT=LDUMMY+8*NWNG
      LOI=LCT+NSW1
      LONN=LOI+NNCW
      LOSWP=LONN+NNCW
      LXVWNA=LOSWP+NNCW
      LYVWNA=LXVWNA+NSW1
      LGAMA=LYVWNA+NSW1
      LGML=LGAMA+NWNG+NSW1
      LXLM=LGML+NSW1
      LTHT=LXLM+NSW1
      LSCL=LTHT+NNCW
      LSCM=LSCL+NSW1
```

```
      LSCD=LSCM+NSW1
      LCOSP=LSCD+NSW1
      LCNC =LCOSP+NNCW
      LCSWL=LCNC+NSW1
      LCSW1=LCSWL+NSW
      LDCPA=LCSW1+NSW1
      LDCP=LDCPA+NSW
      LGMNW=LDCP+NWNP
      LGMY =LGMNW+NWNP
      LVY=LGMY+NWNG+NSW1
      LCOEF=LVY+NWNG
      LDCPN=LCOEF+NSW1*(NNCW+1)
      LWX=LDCPN+NSW1
      LWY=LWX+NWNG+NCW
      LNEXT=LWY+NWNG+NCW
C     LNEXT=28*NWNG+25*NSW+10*NCW-14
      CALL COEFS (D(LCI),D(LCJ),D(LCK),D(LCONI),D(LCONJ),D(LCONK),D(LXVW
     1NG),D(LYVWNG),D(LXLE),D(LXTE),D(LYLE),D(LSI),D(LC),D(LSWP),D(LXN),
     2D(LYN),D(LSNN),D(LTHETP),D(LCONS),D(LDUMMY),D(LCT),D(LQI),D(LONN),
     3D(LQSWP),D(LXVWNA),D(LYVWNA),NWNG,D(LGAMA),D(LGML),D(LXLM),D(LTHT)
     4,D(LSCL),D(LSCM),D(LSCD),D(LCOSP),D(LCNC),D(LCSWL),D(LCSW1),D(LDCP
     5A),D(LDCP),D(LGMNW),D(LGMY),D(LVY),D(LCOEF),D(LDCPN),D(LWX),D(LWY)
     6,W,NSW1)
      RETURN
      END
```

```
      SUBROUTINE COEFS (CI,CJ,CK,CONI,CONJ,CONK,XAVWNG,YAVWNG,XLE,XTE,YL
     1E,SI,C,SWP,XN,YN,SNN,THETP,CONS,DUMMY,CT,OI,ONN,OSWP,XAVWNA,YAVWNA
     2,NWNG,GAMA,GML,XLM,THT,SECCL,SECCM,SECCD,COSP,CNC,CPSWL,CPSW1,DCPA
     3,DCP,GNNW,GMY,VY,COEF,DCPN,WX,WY,W,NSW1)
C     COMPUTES THE AERODYNAMIC CHARACTERSTICS
      COMMON /ALLI/ NSW,NSW3,NCW
      COMMON /ALLRA/ AA(17),SINA,COSA,AB(8),PI,AC,CBAR,HALF3,ARFA
      COMMON /NCTT/ NCT,NCON
      COMMON /XSTN/ XBRR(25),NBRR
      DIMENSION CI(1), CJ(1), CK(1), CONI(1), CONJ(1), CONK(1), XAVWNG(1
     1), YAVWNG(1), XLF(1), XTE(1), YLE(1), SI(1), C(1), SWP(1), SNN(1),
     2 CT(1), XN(NWNG,2), YN(NWNG,2), DUMMY(1), GAMA(1), GML(1), XLM(1),
     3 THT(1), SECCL(1), SECCM(1), SECCD(1), COSP(1), CNC(1), CPSWL(1),
     4CPSW1(1), DCPA(1), DCP(1), GNNW(1), GMY(1), VY(1), DCPN(1), WX(1),
     5 WY(1), W(1), COEF(NSW1,1), CONS(1), THETP(1), OI(1), ONN(1). OSWP
     6(1), XAVWNA(1), YAVWNA(1)
C     ******************************************************************
      REWIND 1
      READ (1) NNCW,NWNP
      READ (1) (OI(I),ONN(I),OSWP(I),I=1,NNCW)
      READ (1) (XAVWNA(I),YAVWNA(I),I=1,NSW1)
      READ (1) (SNN(I),SWP(I),I=1,NCW)
      READ (1) (XAVWNG(I),YAVWNG(I),I=1,NWNG)
      READ (1) (C(I),I=1,NSW1)
      READ (1) (THETP(I),I=1,NSW1)
      READ (1) (XTE(I),XLE(I),YLE(I),I=1,NSW)
      READ (1) (XLM(I),YLM,I=1,NSW1)
      READ (1) (CONS(I),I=1,NSW1)
      READ (1) (SI(I),ADUM,I=1,NSW)
      CALL SKIPR (1,1)
      READ (1) ((XN(I,J),YN(I,J),J=1,2),I=1,NWNG)
      READ (1) (CT(I),I=1,NSW1)
      CALL SKIPR (1,2)
      READ (1) (CPSWL(I),I=1,NSW)
      READ (1) (CPSW1(I),I=1,NSW1)
      NWNG=NWNG+NSW1
      REWIND 2
      READ (2) (CA ...)
C     ******************************************************************
      PIJ=PI/(2.*FLOAT(NCW))
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      DO 10 J=1,NCW                                                     COF 410
10    COSP(J)=COS((2.*FLOAT(J)-1.)*PIJ)                                 COF 420
      CONST=HALFB*PI/(AREA*FLOAT(NSW))                                  COF 430
C     CALCULATION OF GMY-VALUES FOR WING SURFACE                        COF 440
      NCON=0                                                            COF 450
      NCT=0                                                             COF 460
      DO 20 II=1,NSW1                                                   COF 470
      DO 20 J=1,NCW                                                     COF 480
      I=(II-1)*NCW+J                                                    COF 490
      XEE=XAVWNG(I)                                                     COF 500
      YEE=YAVWNG(I)                                                     COF 510
      ZEE=0.                                                            COF 520
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CONCOF 530
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,ADUM,BDUM,CDUM,GAMA,COF 540
     2YLM)                                                              COF 550
      TNSP=TAN(SWP(J))                                                  COF 560
      GMY(I)=GAMA(I)*(UU-VV*TNSP)                                       COF 570
20    CONTINUE                                                          COF 580
C     READING LARGER GRID FOR THE WING                                  COF 590
C     CALCULATION OF INDUCED VELOCITIES AT BOUND ELEMENT END-POINTS ON  COF 600
C     WING SURFACE                                                      COF 610
      DO 40 I=1,NSW1                                                    COF 620
      DO 30 J=1,NCW                                                     COF 630
      NP=(I-1)*NCW+J                                                    COF 640
      XEE=XN(NP,2)                                                      COF 650
      YEE=YN(NP,2)                                                      COF 660
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CONCOF 670
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,ADUM,BDUM,CDUM,GAMA,COF 680
     2YLM)                                                              COF 690
      VY(NP)=VV                                                         COF 700
30    CONTINUE                                                          COF 710
40    CONTINUE                                                          COF 720
C     CALCULATION OF GMY-VALUES FOR BOUND ELEMENTS NEAR LEADING-EDGE    COF 730
      DO 50 J=1,NNCW                                                    COF 740
      FJ=J                                                              COF 750
50    THT(J)=(2.*FJ-1.)*PI/(2.*FLOAT(NNCW))                             COF 760
      CURA=3.*FLOAT(NNCW)/(4.*PI*SIN(THT(1)))                           COF 770
      DO 60 I=1,NSW1                                                    COF 780
      NGI=NWNG+I                                                        COF 790
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60    GML(I)=GAMA(NGI)*SURA/C(I)
C     ......................................................................
      REWIND 3
      WRITE (3) (GML(I),I=1,NSW1)
C     ......................................................................
      TNSP=TAN(OSWP(1))
      DO 70 II=1,NSW1
      XEE=XAVWNA(II)
      YEE=YAVWNA(II)
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CON
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,ADUM,BDUM,CDUM,GAMA,
     2YLM)
      NWNGII=NWNG+II
      GMY(NWNGII)=GML(II)*(UU-VV*TNSP)
70    CONTINUE
C     CALCULATION OF DCP-VALUES FOR WING POINTS
      PN=PI/(FLOAT(NCW))
      DO 80 I=1,NCW
      W(I)=0.
      WX(I)=XN(I,1)
80    WY(I)=YN(I,1)
      DO 150 I=1,NSW1
      DO 140 J=1,NCW
      NP=(I-1)*NCW+J
      VYY=VY(NP)
      CPG=0.
      CPH=0.
      CPI=0.
      DO 100 JJ=1,J
      NPIN=(I-1)*NCW+JJ
      IF (J.EQ.JJ) GO TO 90
      CPG=CPG+GAMA(NPIN)*SI(JJ)
      GO TO 100
90    CPG=CPG+0.5*GAMA(NPIN)*SI(JJ)
100   CONTINUE
      CPG=-CPG+PN*C(I)*VYY
      IF (I.EQ.NSW1) GO TO 130
      DO 120 JJ=1,J
      NPOT=I*NCW+JJ
```

```
      IF (J.EQ.JJ) GO TO 110                                            COF1190
      CPH=CPH+GAMA(NPOT)*SI(JJ)                                         COF1200
      GO TO 120                                                         COF1210
  110 CPH=CPH+0.5*GAMA(NPOT)*SI(JJ)                                     COF1220
  120 CONTINUE                                                          COF1230
      CPH=CPH*PN*C(I+1)*VYY                                             COF1240
  130 CPI=2.*GAMA(NWNG+I)*VYY                                           COF1250
      W(NP+NCW)=CPG+CPH+CPI                                             COF1260
      WX(NP+NCW)=XN(NP,2)                                               COF1270
      WY(NP+NCW)=YN(NP,2)                                               COF1280
  140 CONTINUE                                                          COF1290
  150 CONTINUE                                                          COF1300
      N3=NWNG+NCW+3                                                     COF1310
      CALL SURFSET (N3,WX,WY,W,CI)                                      COF1320
      DO 170 K=1,NCW                                                    COF1330
      DO 160 J=1,NSW1                                                   COF1340
      NP=(J-1)*NCW+K                                                    COF1350
      DCP1=2.*GMY(NP)                                                   COF1360
      XEE=XAVWNG(NP)                                                    COF1370
      YEE=YAVWNG(NP)                                                    COF1380
      CALL SURFORD (W,XEE,YEE,VV,N3)                                    COF1390
      DCPD=VV/(YLE(J+1)-YLE(J))                                         COF1400
      DCP(NP)=DCP1+DCPD                                                 COF1410
  160 CONTINUE                                                          COF1420
  170 CONTINUE                                                          COF1430
C     CALCULATION OF INDUCED VELOCITIES AT END-POINTS OF BOUND ELEMENTS COF1440
C     NEAR LEADING-EDGE                                                 COF1450
      CPC=0.5*(1.-COS(THT(1)))                                          COF1460
      DO 180 I=2,NSW                                                    COF1470
      XEE=XLE(I)+CPC*(XTE(I)-XLE(I))                                    COF1480
      YEE=YLE(I)                                                        COF1490
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CONCOF1500
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,ADUM,BDUM,CDUM,GAMA,COF1510
     2YLM)                                                              COF1520
  180 VY(I)=VV                                                          COF1530
C     DCP-INTERPOLATION FOR BOUND ELEMENTS OF WING                      COF1540
      CALL INTGMY (NCW,NSW1,DCP,SNN,COEF,DUMMY(1),DUMMY(NNCW))          COF1550
C     CALCULATION OF DECREASE IN DCP-VALUES AT THE LEADING-EDGE         COF1560
      DCPA(1)=0.                                                        COF1570
```

```
      DCPA(NSW)=0.                                                      COF1580
      DO 190 I=2,NSW1                                                   COF1590
      DCPA(I)=2.*GAMA(NWNG+I)*VY(I)                                     COF1600
190   CONTINUE                                                          COF1610
      DO 200 I=1,NSW1                                                   COF1620
      CNC(I)=-2.*GMY(NWNG+I)                                            COF1630
200   CONTINUE                                                          COF1640
C     FINAL DCP-VALUES AT LARGER WING GRID                              COF1650
      DO 230 I=1,NSW1                                                   COF1660
      DO 220 J=1,NNCW                                                   COF1670
      NP=(I-1)*NNCW+J                                                   COF1680
      GMNW(NP)=COEF(I,1)                                                COF1690
      DO 210 K=1,NCW                                                    COF1700
      FK=K                                                              COF1710
      AMI1=COS(FK*THT(J))                                               COF1720
      AMI2=AMI1*COEF(I,K+1)                                             COF1730
      GMNW(NP)=GMNW(NP)+AMI2                                            COF1740
210   CONTINUE                                                          COF1750
      GMNW(NP)=GMNW(NP)/(SIN(THT(J)))                                   COF1760
      IF (J.NE.1) GO TO 220                                             COF1770
      NGI=NWNG+I                                                        COF1780
      GMNW(NP)=GMNW(NP)+CNC(I)                                          COF1790
220   CONTINUE                                                          COF1800
230   CONTINUE                                                          COF1810
      DO 240 I=1,NWNP                                                   COF1820
240   DCP(I)=GMNW(I)                                                    COF1830
      PIJ=PI/(2.*FLOAT(NNCW))                                           COF1840
      WRITE (6,370)                                                     COF1850
      DO 250 I=1,NSW1                                                   COF1860
      DO 250 J=1,NNCW                                                   COF1870
      NP=(I-1)*NNCW+J                                                   COF1880
      CPCW=0.5*(1.-COS((2.*FLOAT(J)-1.)*PIJ))                           COF1890
250   WRITE (6,380) CPCW,CPSW1(I),DCP(NP)                               COF1900
      DO 260 J=1,NNCW                                                   COF1910
260   COSP(J)=COS((2.*FLOAT(J)-1.)*PIJ)                                 COF1920
C     EVALUATION OF SECTIONAL AND TOTAL AERODYNAMIC CHARACTERSTICS      COF1930
      CL=0.                                                             COF1940
      CM=0.                                                             COF1950
      CD=0.                                                             COF1960
```

```
      CTT=0.                                                            COF1970
      DO 280 I=1,NSW1                                                   COF1980
      SECCL(I)=0.                                                       COF1990
      SECCM(I)=0.                                                       COF2000
      PHII=PI*FLOAT(I)/FLOAT(NSW)                                       COF2010
      DO 270 J=1,NNCW                                                   COF2020
      NP=(I-1)*NNCW+J                                                   COF2030
      SECCL(I)=SECCL(I)+DCP(NP)*QI(J)                                   COF2040
      SECCM(I)=SECCM(I)-DCP(NP)*QI(J)*(XLM(I)+0.5*C(I)*(1.-COSP(J)))/CBACOF2050
     1R                                                                 COF2060
  270 CONTINUE                                                          COF2070
      SECCL(I)=SECCL(I)*PI/(2.*FLOAT(NNCW))                             COF2080
      SECCM(I)=SECCM(I)*PI/(2.*FLOAT(NNCW))                             COF2090
      SECCD(I)=SECCL(I)*SINA-CT(I)*COSA                                 COF2100
      SECCL(I)=SECCL(I)*COSA+CT(I)*SINA                                 COF2110
      CL=CL+SECCL(I)*C(I)*SIN(PHII)                                     COF2120
      CM=CM+SECCM(I)*C(I)*SIN(PHII)                                     COF2130
      CD=CD+SECCD(I)*C(I)*SIN(PHII)                                     COF2140
  280 CTT=CTT+CT(I)*C(I)*SIN(PHII)                                      COF2150
      CL=CONST*CL                                                       COF2160
      CM=CONST*CM                                                       COF2170
      CD=CONST*CD                                                       COF2180
      CTT=CONST*CTT                                                     COF2190
C     ..................................................................COF2200
      WRITE (7) CL,CM,CD,CTT                                            COF2210
C     ..................................................................COF2220
      WRITE (6,340) (I,SECCL(I),SECCM(I),SECCD(I),CT(I),I=1,NSW1)       COF2230
      WRITE (6,350) CL,CM,CD,CTT                                        COF2240
      NNCW1=NNCW+1                                                      COF2250
      CALL INTGMY (NNCW,NSW1,DCP,QNN,COEF,DUMMY(1),DUMMY(NNCW1))        COF2260
      REWIND 1                                                          COF2270
      CALL SKIPR (1,8)                                                  COF2280
      READ (1) (XLM(I),CI(I),I=1,NSW1)                                  COF2290
C     EVALUATION OF DCP AT CONSTANT X LOCATIONS                         COF2300
      DO 330 K=1,NBRR                                                   COF2310
      XBR=XBRR(K)                                                       COF2320
      KY=1                                                              COF2330
  290 IF (XBR.LT.XLM(KY)) GO TO 300                                     COF2340
      KY=KY+1                                                           COF2350
```

```
      IF (KY.LE.NSW1) GO TO 290                                         COF2360
300   KY=KY-1                                                           COF2370
      BLOCAL=CI(KY)+(CI(KY+1)-CI(KY))*(XBR-XLM(KY))/(XLM(KY+1)-XLM(KY)) COF2380
      DO 320 I=1,KY                                                     COF2390
      CJ(I)=CI(I)/BLOCAL                                                COF2400
      XC=(XBR-XLM(I))/C(I)                                              COF2410
      THTA=ARCOS(1.-2.*XC)                                              COF2420
      DCPN(I)=COEF(I,1)                                                 COF2430
      DO 310 J=1,NNCW                                                   COF2440
310   DCPN(I)=DCPN(I)+COEF(I,J+1)*COS(FLOAT(J)*THTA)                    COF2450
320   DCPN(I)=DCPN(I)/(SIN(THTA))                                       COF2460
      WRITE (6,360) XBR,(CI(I),CJ(I),DCPN(I),I=1,KY)                    COF2470
330   CONTINUE                                                          COF2480
      RETURN                                                            COF2490
C                                                                       COF2500
340   FORMAT (1H1,//,9X,20HSECTIONAL PROPERTIES,/,9X,20H****************COF2510
     1****,//,9X,39HI      CLI        CMI        CDI        CTI,/,9X,39H*  COF2520
     2  ***       ***        ***        ***,/,(I10,4F10.5))             COF2530
350   FORMAT (/,9X,23HTOTAL LIFT COEFFICIENT=,F10.5,/,9X,34HTOTAL PITCHICOF2540
     1NG MOMENT COEFFICIENT=,F10.5,/,9X,23HTOTAL DRAG COEFFICIENT=,F10.5COF2550
     2,/,9X,25HTOTAL THRUST COEFFICIENT=,F10.5)                         COF2560
360   FORMAT (//,34H SPANWISE PRESSURES AT CONSTANT X=,F10.5,/,8X,25HY  COF2570
     1  2Y/B(LOCAL) DELTA-CP,/,(1X,2F10.5,2X,F10.5))                    COF2580
370   FORMAT (1H1,//,5X,21HDELTA-CP DISTRIBUTION,/,5X,21H***************COF2590
     1******,/,30H       X/C       2Y/B   DELTA-CP,/,30H       ***     ***COF2600
     2*   ********)                                                     COF2610
380   FORMAT (3F10.5)                                                   COF2620
      END                                                               COF2630-
```

```
      SUBROUTINE INTGMY (NCW,NSW1,SGM,SNN,COEF,F,THETA)
C     SETS UP COEFFICIENTS OF A MATRIX FOR DCP-INTERPOLATION
      DIMENSION SGM(1), SNN(1), F(1), THETA(1), COEF(NSW1,1)
      PI=3.14159265
      N1=NCW+1
      FN=NCW
      DO 40 I=1,NSW1
      DO 10 J=1,NCW
      NK=(I-1)*NCW+J
      FJ=J
      THETA(J)=(2.*FJ-1.)*PI/(2.*FN)
10    F(J)=SGM(NK)*SNN(J)
      DO 30 J=1,N1
      COEF(I,J)=0.
      FJ=J
      DO 20 K=1,NCW
20    COEF(I,J)=COEF(I,J)+F(K)*COS((FJ-1.)*THETA(K))
      IF (J.EQ.1) COEF(I,J)=COEF(I,J)/FN
      IF (J.NE.1) COEF(I,J)=COEF(I,J)*2./FN
30    CONTINUE
40    CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SURFSET (N3,X,Y,W,IWK)                                 SRF  10
C       SET UP PROGRAM FOR SURFACE SPLINE                               SRF  20
C       WRITTEN BY - ROBERT N. DESMARAIS, STRUCTURES AND DYNAMICS DIV.  SRF  30
C                     LANGLEY RESEARCH CENTER, HAMPTON, VA.23665        SRF  40
      DIMENSION X(1), Y(1), W(N3,1), IWK(1)                             SRF  50
      E=1.E-10                                                          SRF  60
      NZ=1                                                              SRF  70
      N=N3-3                                                            SRF  80
      N1=N+1                                                            SRF  90
      N2=N+2                                                            SRF 100
      N4=N3+1                                                           SRF 110
      RN=1./N                                                           SRF 120
      N3Z=N3+NZ                                                         SRF 130
      NZ3=NZ+3                                                          SRF 140
C       COMPUTE SCALING PARAMETERS, UB,UX,UY,VB,VX,XY                   SRF 150
      XB=0.                                                             SRF 160
      YB=0.                                                             SRF 170
      PXX=0.                                                            SRF 180
      PXY=0.                                                            SRF 190
      PYY=0.                                                            SRF 200
      TH=0.                                                             SRF 210
      DO 10 I=1,N                                                       SRF 220
      XB=XB+X(I)                                                        SRF 230
      YB=YB+Y(I)                                                        SRF 240
      PXX=PXX+X(I)*X(I)                                                 SRF 250
      PXY=PXY+X(I)*Y(I)                                                 SRF 260
   10 PYY=PYY+Y(I)*Y(I)                                                 SRF 270
      XB=RN*XB                                                          SRF 280
      YB=RN*YB                                                          SRF 290
      PXX=RN*PXX-XB*XB                                                  SRF 300
      PXY=RN*PXY-XB*YB                                                  SRF 310
      PYY=RN*PYY-YB*YB                                                  SRF 320
      IF (PXY.NE.0) TH=.5*ATAN2(2.*PXY,PYY-PXX)                         SRF 330
      CT=COS(TH)                                                        SRF 340
      ST=SIN(TH)                                                        SRF 350
      C2=CT*CT                                                          SRF 360
      CS=2.*CT*ST                                                       SRF 370
      S2=ST*ST                                                          SRF 380
      SU=1./SQRT(PXX*C2-PXY*CS+PYY*S2)                                  SRF 390
      SV=1./SQRT(PXX*S2+PXY*CS+PYY*C2)                                  SRF 400
```

```
      UX=SU*CT
      UY=-SU*ST
      VX=SV*ST
      VY=SV*CT
      UB=-(UX*XB+UY*YB)
      VB=-(VX*XB+VY*YB)
C       PUT Z INTO ITS W LOCATION
      IZ=N*NZ
      DO 30 J=N4,N3Z
      DO 20 I=1,3
20    W(I,J)=0
      DO 30 I=4,N3
      W(I,N3Z+N4-J)=W(IZ,1)
30    IZ=IZ-1
C       PUT 1,U,V (SCALED X,Y) INTO THEIR W LOCATIONS
      DO 40 J=N1,N3
      DO 40 I=1,3
40    W(I,J)=0
      DO 50 J=1,N
      JB=N4-J
      W(1,J)=1.
      W(JB,N1)=W(1,J)
      W(2,J)=UB+UX*X(J)+UY*Y(J)
      W(JB,N2)=W(2,J)
      W(3,J)=VB+VX*X(J)+VY*Y(J)
50    W(JB,N3)=W(3,J)
      DO 60 J=1,N
      JB=N4-J
C       COMPUTE H MATRIX IN W
      DO 60 I=4,JB
      IB=N4-I
      R2=(W(2,J)-W(2,IB))**2+(W(3,J)-W(3,IB))**2
      W(I,J)=R2*ALOG(R2+E)
60    W(JB,IB)=W(I,J)
C      MATINV IS THE SYSTEM LIBRARY ROUTINE FOR SOLVING LINEAR EQUATIONS
      N31=N3+1
      CALL MATINV (N3,N3,W,1,W(1,N31),1,DET,ISC,IWK,IWK(N4))
C       PUT S,U,V IN LOW W
      W(1,1)=N3*(3.+NZ)
```

```
      W(2,1)=N
      W(3,1)=E
      DO 70 I=1,N
      W(I+3,1)=0
      W(I,2)=UB+UX*X(I)+UY*Y(I)
70    W(I,3)=VB+VX*X(I)+VY*Y(I)
      W(N1,2)=UB
      W(N2,2)=UX
      W(N3,2)=UY
      W(N1,3)=VB
      W(N2,3)=VX
      W(N3,3)=VY
      IF (NZ.EQ.0) RETURN
      DO 80 J=4,NZ3
      DO 80 I=1,N3
C       LEFT SHIFT A,B MATRICES N COLUMNS
80    W(I,J)=W(I,N+J)
      RETURN
      END
```

```
      SUBROUTINE SURFORD (W,XP,YP,ZP,N3)                                ORD  10
C       SURFACE SPLINE INTERPOLATION (ORDINATES)                        ORD  20
C       WRITTEN BY - ROBERT N. DESMARAIS, STRUCTURES AND DYNAMICS DIV.  ORD  30
C                    LANGLEY RESEARCH CENTER, HAMPTON, VA.23665         ORD  40
      DIMENSION W(N3,1)                                                 ORD  50
      N=N3-3                                                            ORD  60
      N1=N+1                                                            ORD  70
      N2=N+2                                                            ORD  80
      U=W(N1,2)+W(N2,2)*XP+W(N3,2)*YP                                   ORD  90
      V=W(N1,3)+W(N2,3)*XP+W(N3,3)*YP                                   ORD 100
      ZP=W(N1,4)+W(N2,4)*U+W(N3,4)*V                                    ORD 110
      DO 10 I=1,N                                                       ORD 120
      R2=(U-W(I,2))**2+(V-W(I,3))**2                                    ORD 130
   10 ZP=ZP+W(I,4)*R2*ALOG(R2+W(3,1))                                   ORD 140
      RETURN                                                            ORD 150
      END                                                               ORD 160-
```

```
      SUBROUTINE MATINV (MAX,N,A,M,B,IOP,DETERM,ISCALE,IPIVOT,IWK)
C     MATRIX INVERSION WITH ACCOMPANYING SOLUTION OF LINEAR EQUATIONS
C     PROVIDED BY - ANALYSIS AND COMPUTATION DIVISION
C                   LANGLEY RESEARCH CENTER
C                   HAMPTON, VA. 23665
      DIMENSION IPIVOT(N), A(MAX,N), B(MAX,N), IWK(MAX,2)
      EQUIVALENCE (IROW,JROW), (ICOLUM,JCOLUM), (AMAX,T,SWAP)
C
C     INITIALIZATION
C
      ISCALE=0
      R1=10.0**100
      R2=1.0/R1
      DETERM=1.0
      DO 10 J=1,N
10    IPIVOT(J)=0
      DO 370 I=1,N
C
C     SEARCH FOR PIVOT ELEMENT
C
      AMAX=0.0
      DO 60 J=1,N
      IF (IPIVOT(J)-1) 20,60,20
20    DO 50 K=1,N
      IF (IPIVOT(K)-1) 30,50,410
30    IF (ABS(AMAX)-ABS(A(J,K))) 40,50,50
40    IROW=J
      ICOLUM=K
      AMAX=A(J,K)
50    CONTINUE
60    CONTINUE
      IF (AMAX) 80,70,80
70    DETERM=0.0
      ISCALE=0
      GO TO 410
80    IPIVOT(ICOLUM)=IPIVOT(ICOLUM)+1
C
C     INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL
C
      IF (IROW-ICOLUM) 90,130,90
```

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OF POOR QUALITY

```
90    DETERM=-DETERM
      DO 100 L=1,N
      SWAP=A(IROW,L)
      A(IROW,L)=A(ICOLUM,L)
100   A(ICOLUM,L)=SWAP
      IF (M) 130,130,110
110   DO 120 L=1,M
      SWAP=B(IROW,L)
      B(IROW,L)=B(ICOLUM,L)
120   B(ICOLUM,L)=SWAP
130   IWK(I,1)=IROW
      IWK(I,2)=ICOLUM
      PIVOT=A(ICOLUM,ICOLUM)
      IF (IOP.EQ.1) GO TO 270
      IF (PIVOT) 140,70,140
C
C     SCALE THE DETERMINANT
C
140   PIVOTI=PIVOT
      IF (ABS(DETERM)-R1) 170,150,150
150   DETERM=DETERM/R1
      ISCALE=ISCALE+1
      IF (ABS(DETERM)-R1) 200,160,160
160   DETERM=DETERM/R1
      ISCALE=ISCALE+1
      GO TO 200
170   IF (ABS(DETERM)-R2) 180,180,200
180   DETERM=DETERM*R1
      ISCALE=ISCALE-1
      IF (ABS(DETERM)-R2) 190,190,200
190   DETERM=DETERM*R1
      ISCALE=ISCALE-1
200   IF (ABS(PIVOTI)-R1) 230,210,210
210   PIVOTI=PIVOTI/R1
      ISCALE=ISCALE+1
      IF (ABS(PIVOTI)-R1) 250,220,220
220   PIVOTI=PIVOTI/R1
      ISCALE=ISCALE+1
      GO TO 240
```

```
230   IF (ABS(PIVOTI)-R2) 240,240,260                    MAT 800
240   PIVOTI=PIVOTI*R1                                   MAT 810
      ISCALE=ISCALE-1                                    MAT 820
      IF (ABS(PIVOTI)-R2) 250,250,260                    MAT 830
250   PIVOTI=PIVOTI*R1                                   MAT 840
      ISCALE=ISCALE-1                                    MAT 850
260   DETERM=DETERM*PIVOTI                               MAT 860
C                                                        MAT 870
C     DIVIDE PIVOT ROW BY PIVOT ELEMENT                  MAT 880
C                                                        MAT 890
270   IF (PIVOT) 280,70,280                              MAT 900
280   A(ICOLUM,ICOLUM)=1.0                               MAT 910
      DO 290 L=1,N                                       MAT 920
290   A(ICOLUM,L)=A(ICOLUM,L)/PIVOT                      MAT 930
      IF (M) 320,320,300                                 MAT 940
300   DO 310 L=1,M                                       MAT 950
310   B(ICOLUM,L)=B(ICOLUM,L)/PIVOT                      MAT 960
C                                                        MAT 970
C     REDUCE NON-PIVOT ROWS                              MAT 980
C                                                        MAT 990
320   DO 370 L1=1,N                                      MAT1000
      IF (L1-ICOLUM) 330,370,330                         MAT1010
330   T=A(L1,ICOLUM)                                     MAT1020
      A(L1,ICOLUM)=0.0                                   MAT1030
      DO 340 L=1,N                                       MAT1040
340   A(L1,L)=A(L1,L)-A(ICOLUM,L)*T                      MAT1050
      IF (M) 370,370,350                                 MAT1060
350   DO 360 L=1,M                                       MAT1070
360   B(L1,L)=B(L1,L)-B(ICOLUM,L)*T                      MAT1080
370   CONTINUE                                           MAT1090
C                                                        MAT1100
C     INTERCHANGE COLUMNS                                MAT1110
C                                                        MAT1120
      DO 400 I=1,N                                       MAT1130
      L=N+1-I                                            MAT1140
      IF (IWK(L,1)-IWK(L,2)) 380,400,380                 MAT1150
380   JROW=IWK(L,1)                                      MAT1160
      JCOLUM=IWK(L,2)                                    MAT1170
      DO 390 K=1,N                                       MAT1180
```

```
      SWAP=A(K,JROW)                                                    MAT1190
      A(K,JROW)=A(K,JCOLUM)                                             MAT1200
      A(K,JCOLUM)=SWAP                                                  MAT1210
  390 CONTINUE                                                          MAT1220
  400 CONTINUE                                                          MAT1230
  410 RETURN                                                            MAT1240
      END                                                               MAT1250-
```

```
      OVERLAY (LEVSP,5,0)                                               NSP  10
      PROGRAM NEWSHAP                                                   NSP  20
C     SETS UP DIMENSIONS FOR COMPUTING THE NEW LOCATIONS OF LEADING-EDGENSP  30
C     AND TRAILING-EDGE VORTICES BY MAKING THOSE FORCE-FREE             NSP  40
      COMMON D(1)                                                       NSP  50
      COMMON /ALLI/ NSW,NSW1,NCW,NWNG,NCPTTL                            NSP  60
      DIMENSION E(2400)                                                 NSP  70
C     ******************************************************************NSP  80
      REWIND 4                                                          NSP  90
      NN=NSW1+NSW                                                       NSP 100
      CALL SKIPR (4,NN)                                                 NSP 110
      READ (4) NMAX,NNMAX,ZMIN,NCONTS                                   NSP 120
C     ******************************************************************NSP 130
      LC=1                                                              NSP 140
      LTHETP=LC+NSW1                                                    NSP 150
      LXN=LTHETP+NSW1                                                   NSP 160
      LYN=LXN+2*NWNG                                                    NSP 170
      LXTE=LYN+2*NWNG                                                   NSP 180
      LXLE=LXTE+NSW                                                     NSP 190
      LYLE=LXLE+NSW                                                     NSP 200
      LCONS=LYLE+NSW                                                    NSP 210
      LSI=LCONS+NSW1                                                    NSP 220
      LXCP=LSI+NCW                                                      NSP 230
      LYCP=LXCP+NCPTTL                                                  NSP 240
      LCI=LYCP+NCPTTL                                                   NSP 250
      LCJ=LCI+NWNG                                                      NSP 260
      LCK=LCJ+NWNG                                                      NSP 270
      LCONI=LCK+NWNG                                                    NSP 280
      LCONJ=LCONI+NWNG                                                  NSP 290
      LCONK=LCONJ+NWNG                                                  NSP 300
      LDUMY=LCONK+NWNG                                                  NSP 310
      LNELM=LDUMY+8*NWNG                                                NSP 320
      LNNELM=LNELM+NSW1                                                 NSP 330
      LGAMA=LNNELM+NSW                                                  NSP 340
      LGML=LGAMA+NCPTTL                                                 NSP 350
      LYLM=LGML+NSW1                                                    NSP 360
      LCPCW=LYLM+NSW1                                                   NSP 370
      LNEXT=LCPCW+NSW1                                                  NSP 380
C     LNEXT=21*NWNG+14*NSW+NCW-9                                        NSP 390
      MXE=1                                                             NSP 400
```

```
      MYE=MXE+NSW1*NMAX                                                 NSP 410
      MZE=MYE+NSW1*NMAX                                                 NSP 420
      MXXE=MZE+NSW1*NMAX                                                NSP 430
      MYYE=MXXE+NSW*NNMAX                                               NSP 440
      MZZE=MYYE+NSW*NNMAX                                               NSP 450
      MNEXT=MZZE+NSW*NNMAX                                              NSP 460
C     MNEXT=3*NSW*NMAX-3*NMAX+3*NSW*NNMAX+1                             NSP 470
      CALL NEWELM (D(LC),D(LTHETP),D(LXN),D(LYN),D(LXTE),D(LXLE),D(LYLE)NSP 480
     1,D(LCONS),D(LSI),D(LXCP),D(LYCP),D(LCI),D(LCJ),D(LCK),D(LCONI),D(LNSP 490
     2CONJ),D(LCONK),D(LDUMY),NWNG,NCPTTL,E(MXE),E(MYE),E(MZE),E(MXXE),ENSP 500
     3(MYYE),E(MZZE),NSW1,NSW,NCW,ZMIN,NMAX,NNMAX,D(LNELM),D(LNNELM),NCONSP 510
     4NTS,D(LGAMA),D(LGML),D(LYLM),D(LCPCW))                            NSP 520
      RETURN                                                            NSP 530
      END                                                               NSP 540-
```

```
      SUBROUTINE NEWELM (C,THETP,XN,YN,XTE,XLE,YLE,CONS,SI,XCP,YCP,CI,CJ
     1,CK,CONI,CONJ,CONK,DUMMY,NWNG,NCPTTL,XE,YE,ZE,XXE,YYE,ZZE,NSW1,NSW
     2,NCW,ZMIN,NMAX,NNMAX,NELM,NNELM,NCONTS,GAMA,GML,YLM,CPCW1)
C     COMPUTES THE NEW LOCATIONS OF LEADING-EDGE AND TRAILING-EDGE
C     VORTICES BY MAKING THOSE FORCE-FREE
      COMMON /GM/ ITER
      COMMON /NCTT/ NCT,NCON
      COMMON /ALLRA/ TTL(16),ALPHA,SINA,AA(9),PI,AD(2),HALFB,AREA
      DIMENSION DUMMY(1), CONI(1), CONJ(1), CONK(1), CI(1), CJ(1), CK(1)
     1, C(1), THETP(1), XTE(1), XLE(1), YLE(1), CONS(1), SI(1), XCP(1),
     2YCP(1), GAMA(1), GML(1), YLM(1), CPCW1(1), XN(NWNG,2), YN(NWNG,2),
     3 NELM(1), NNELM(1), XE(NSW1,1), YE(NSW1,1), ZE(NSW1,1), XXE(NSW,1)
     4, YYE(NSW,1), ZZE(NSW,1), A(3), B(3), F(3)
C     ..................................................................
      REWIND 1
C     ******************************************************************
      CALL SKIPR (1,5)
      READ (1) (C(I),I=1,NSW1)
      READ (1) (THETP(I),I=1,NSW1)
      READ (1) (XTE(I),XLE(I),YLE(I),I=1,NSW)
      READ (1) (XLM,YLM(I),I=1,NSW1)
      READ (1) (CONS(I),I=1,NSW1)
      READ (1) (SI(I),AC,I=1,NCW)
      READ (1) (XCP(I),YCP(I),I=1,NCPTTL)
      READ (1) ((XN(I,J),YN(I,J),J=1,2),I=1,NWNG)
      CALL SKIPR (1,2)
      READ (1) (CPCW1(I),I=1,NCW)
      REWIND 2
      READ (2) (GAMA(I),I=1,NCPTTL)
      REWIND 3
      READ (3) (GML(I),I=1,NSW1)
      REWIND 4
      DO 10 I=1,NSW1
      READ (4) KK,(XE(I,J),YE(I,J),ZE(I,J),J=1,KK)
   10 NELM(I)=KK
      DO 20 I=1,NSW
      READ (4) KK,(XXE(I,J),YYE(I,J),ZZE(I,J),J=1,KK)
   20 NNELM(I)=KK
C     ******************************************************************
      BHALF=1.25*HALFB
```

```
      ATL=1.-0.1*FLOAT(ITER)
      IF (NCONTS.NE.0) ATL=0.75
      IF (ATL.LT.0.75) ATL=0.75
      BTL=1.-ATL
C     EVALUATION OF FORCE ACTING ON LEADING-EDGE ELEMENTS
      TFABS=0.
      TLNTH=0.
      NCT=0
      DO 40 I=2,NSW1
      NCON=I
      K=NELM(I)-1
      FABS=0.
      ALNTH=0.
      DO 30 J=5,K
      XEE=(XE(I,J)+XE(I,J+1))/2.
      YEE=(YE(I,J)+YE(I,J+1))/2.
      ZEE=(ZE(I,J)+ZE(I,J+1))/2.
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CON
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,CPCW1,XCP,YCP,GAMA,YN
     2LM)
      GMA=GAMA(NWNG+I)
      A(1)=XE(I,J+1)-XE(I,J)
      A(2)=YE(I,J+1)-YE(I,J)
      A(3)=ZE(I,J+1)-ZE(I,J)
      AAA=SQRT(A(1)*A(1)+A(2)*A(2)+A(3)*A(3))
      A(1)=A(1)*GMA/AREA
      A(2)=A(2)*GMA/AREA
      A(3)=A(3)*GMA/AREA
      B(1)=UU
      B(2)=VV
      B(3)=WW
      CALL CRSPRD (A,B,F)
      FABSI=SQRT(F(1)*F(1)+F(2)*F(2)+F(3)*F(3))
      FABS=FABS+FABSI
      ALNTH=ALNTH+AAA
   30 CONTINUE
      TFABS=TFABS+FABS
      TLNTH=TLNTH+ALNTH
   40 CONTINUE
```

```
      TAVRG=TFABS/TLNTH                                                 NLM 800
      WRITE (6,170) TFABS                                               NLM 810
C     ..................................................................NLM 820
      WRITE (7) TFABS,TAVRG,TLNTH                                       NLM 030
C     ..................................................................NLM 840
C     CALCULATION OF THE COORDINATES OF LEADING-EDGE ELEMENTS BY        NLM 850
C     SATISFYING FORCE-FREE CONDITION                                   NLM 860
      DO 110 J=5,NMAX                                                   NLM 870
      DO 110 I=2,NSW1                                                   NLM 880
      NCON=I                                                            NLM 890
      K=NELM(I)-1                                                       NLM 900
      IF (J.GT.K) GO TO 110                                             NLM 910
      XXX=XE(I,J+1)                                                     NLM 920
      YYY=YE(I,J+1)                                                     NLM 930
      ZZZ=ZE(I,J+1)                                                     NLM 940
      DLS=SQRT((XE(I,J+1)-XE(I,J))**2+(YE(I,J+1)-YE(I,J))**2+(ZE(I,J+1)-NLM 950
     1ZE(I,J))**2)                                                      NLM 960
      XEE=(XE(I,J)+XE(I,J+1))/2.                                        NLM 970
      YEE=(YE(I,J)+YE(I,J+1))/2.                                        NLM 980
      ZEE=(ZE(I,J)+ZE(I,J+1))/2.                                        NLM 990
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CONNLM1000
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,CPCW1,XCP,YCP,GAMA,YNLM1010
     2LM)                                                               NLM1020
      UVW=SQRT(UU*UU+VV*VV+WW*WW)                                       NLM1030
      IF (J.EQ.5) GO TO 50                                              NLM1040
      VVA=ATL*VV/UVW                                                    NLM1050
      WWA=ATL*WW/UVW                                                    NLM1060
      DLY=VVA*DLS+BTL*(YE(I,J+1)-YE(I,J))                               NLM1070
      DLZ=WWA*DLS+BTL*(ZE(I,J+1)-ZE(I,J))                               NLM1080
      GO TO 60                                                          NLM1090
   50 CONTINUE                                                          NLM1100
      VVA=0.5*VV/UVW                                                    NLM1110
      WWA=0.5*WW/UVW                                                    NLM1120
      DLY=VVA*DLS+0.5*(YE(I,J+1)-YE(I,J))                               NLM1130
      DLZ=WWA*DLS+0.5*(ZE(I,J+1)-ZE(I,J))                               NLM1140
      GO TO 70                                                          NLM1150
   60 CONTINUE                                                          NLM1160
      IF ((DLZ/DLS).GT.SINA) DLZ=DLS*SINA                               NLM1170
   70 CONTINUE                                                          NLM1180
```

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      YINT=YE(I,J)+DLY                                                  NLM1190
      ZINT=ZE(I,J)+DLZ                                                  NLM1200
      IF (YINT.LE.YE(2,5)) YINT=YE(2,5)                                 NLM1210
      IF (YINT.GE.BHALF) YINT=BHALF                                     NLM1220
      IF (ZINT.LE.ZMIN) ZINT=ZMIN                                       NLM1230
      DLY2=YINT-YE(I,J)                                                 NLM1240
      DLZ2=ZINT-ZE(I,J)                                                 NLM1250
      DLX22=DLS*DLS-DLY2*DLY2-DLZ2*DLZ2                                 NLM1260
      IF (DLX22.LE.0.) DLY2=DLY2/2.                                     NLM1270
      IF (DLX22.LE.0.) DLZ2=DLZ2/2.                                     NLM1280
      DLX2=SQRT(DLS*DLS-DLY2*DLY2-DLZ2*DLZ2)                            NLM1290
      XE(I,J+1)=XE(I,J)+DLX2                                            NLM1300
      YE(I,J+1)=YE(I,J)+DLY2                                            NLM1310
      ZE(I,J+1)=ZE(I,J)+DLZ2                                            NLM1320
      DX=XE(I,J+1)-XXX                                                  NLM1330
      DY=YE(I,J+1)-YYY                                                  NLM1340
      DZ=ZE(I,J+1)-ZZZ                                                  NLM1350
      J2=J+2                                                            NLM1360
      KP=K+1                                                            NLM1370
      IF (J2.GT.KP) GO TO 110                                           NLM1380
      DO 80 JK=J2,KP                                                    NLM1390
      XE(I,JK)=XE(I,JK)+DX                                              NLM1400
      YE(I,JK)=YE(I,JK)+DY                                              NLM1410
80    ZE(I,JK)=ZE(I,JK)+DZ                                              NLM1420
C     ..................................................................NLM1430
      REWIND 4                                                          NLM1440
      DO 90 L=1,NSW1                                                    NLM1450
      KS=NELM(L)                                                        NLM1460
90    WRITE (4) KS,(XE(L,M),YE(L,M),ZE(L,M),M=1,KS)                     NLM1470
      DO 100 L=1,NSW                                                    NLM1480
      KS=NNELM(L)                                                       NLM1490
100   WRITE (4) KS,(XXE(L,M),YYE(L,M),ZZE(L,M),M=1,KS)                  NLM1500
      WRITE (4) NMAX,NNMAX,ZMIN,NCONTS                                  NLM1510
C     ..................................................................NLM1520
110   CONTINUE                                                          NLM1530
C     CALCULATION OF THE COORDINATES OF WAKE ELEMENTS BY SATISFYING     NLM1540
C     FORCE-FREE CONDITION                                              NLM1550
      CTL=0.5                                                           NLM1560
      DTL=1.-CTL                                                        NLM1570
```

```
      NCON=0                                                            NLM1580
      DO 160 J=1,NNMAX                                                  NLM1590
      DO 160 I=2,NSW                                                    NLM1600
      NCT=I                                                             NLM1610
      K=NNELM(I)-1                                                      NLM1620
      IF (J.GT.K) GO TO 160                                             NLM1630
      XXX=XXE(I,J+1)                                                    NLM1640
      YYY=YYE(I,J+1)                                                    NLM1650
      ZZZ=ZZE(I,J+1)                                                    NLM1660
      WLS=SQRT((XXE(I,J+1)-XXE(I,J))**2+(YYE(I,J+1)-YYE(I,J))**2+(ZZE(I,NLM1670
     1J+1)-ZZE(I,J))**2)                                                NLM1680
      XEE=(XXE(I,J)+XXE(I,J+1))/2.                                      NLM1690
      YEE=(YYE(I,J)+YYE(I,J+1))/2.                                      NLM1700
      ZEE=(ZZE(I,J)+ZZE(I,J+1))/2.                                      NLM1710
      CALL NEWVEL (C,THETP,XEE,YEE,ZEE,XN,YN,XTE,YLE,CONS,DUMMY,CONI,CONNLM1720
     1J,CONK,SI,NSW1,NCW,NWNG,CI,CJ,CK,XLE,UU,VV,WW,CPCW1,XCP,YCP,GAMA,YNLM1730
     2LM)                                                               NLM1740
      UVW=SQRT(UU*UU+VV*VV+WW*WW)                                       NLM1750
      IF (J.EQ.1) GO TO 130                                             NLM1760
      VVA=CTL*VV/UVW                                                    NLM1770
      WWA=CTL*WW/UVW                                                    NLM1780
      DLY=VVA*WLS+DTL*(YYE(I,J+1)-YYE(I,J))                             NLM1790
      DLZ=WWA*WLS+DTL*(ZZE(I,J+1)-ZZE(I,J))                             NLM1800
      IF ((DLZ/WLS).GT.SINA) DLZ=WLS*SINA                               NLM1810
      YINT=YYE(I,J)+DLY                                                 NLM1820
      IF (YINT.LE.(YLE(2)/2.)) YINT=YLE(2)/2.                           NLM1830
      IF (YINT.GE.BHALF) YINT=BHALF                                     NLM1840
      DLY2=YINT-YYE(I,J)                                                NLM1850
      DLZ2=DLZ                                                          NLM1860
      DLX22=WLS*WLS-DLY2*DLY2-DLZ2*DLZ2                                 NLM1870
      IF (DLX22.LE.0.) DLY2=DLY2/2.                                     NLM1880
      IF (DLX22.LE.0.) DLZ2=DLZ2/2.                                     NLM1890
      DLX2=SQRT(WLS*WLS-DLY2*DLY2-DLZ2*DLZ2)                            NLM1900
      XXE(I,J+1)=XXE(I,J)+DLX2                                          NLM1910
      YYE(I,J+1)=YYE(I,J)+DLY2                                          NLM1920
      ZZE(I,J+1)=ZZE(I,J)+DLZ2                                          NLM1930
      DX=XXE(I,J+1)-XXX                                                 NLM1940
      DY=YYE(I,J+1)-YYY                                                 NLM1950
      DZ=ZZE(I,J+1)-ZZZ                                                 NLM1960
```

```
      J2=J+2                                                            NLM1970
      KP=K+1                                                            NLM1980
      IF (J2.GT.KP) GO TO 130                                           NLM1990
      DO 120 JK=J2,KP                                                   NLM2000
      XXE(I,JK)=XXE(I,JK)+DX                                            NLM2010
      YYE(I,JK)=YYE(I,JK)+DY                                            NLM2020
  120 ZZE(I,JK)=ZZE(I,JK)+DZ                                            NLM2030
  130 CONTINUE                                                          NLM2040
C     ..................................................................NLM2050
      REWIND 4                                                          NLM2060
      DO 140 L=1,NSW1                                                   NLM2070
      KS=NELM(L)                                                        NLM2080
  140 WRITE (4) KS,(XE(L,M),YE(L,M),ZE(L,M),M=1,KS)                     NLM2090
      DO 150 L=1,NSW                                                    NLM2100
      KS=NNELM(L)                                                       NLM2110
  150 WRITE (4) KS,(XXE(L,M),YYE(L,M),ZZE(L,M),M=1,KS)                  NLM2120
      WRITE (4) NMAX,NNMAX,ZMIN,NCCNTS                                  NLM2130
C     ..................................................................NLM2140
  160 CONTINUE                                                          NLM2150
      RETURN                                                            NLM2160
C                                                                       NLM2170
  170 FORMAT (//,59H TOTAL ABSOLUTE FORCE ACTING ON LEADING-EDGE FREE ELNLM2180
     1EMENTS=,F10.5)                                                    NLM2190
      END                                                               NLM2200-
```

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-145362		

4. Title and Subtitle A COMPUTER PROGRAM FOR CALCULATING AERODYNAMIC CHARACTERISTICS OF LOW-ASPECT-RATIO WINGS WITH PARTIAL LEADING-EDGE SEPARATION	5. Report Date May 1978
	6. Performing Organization Code
7. Author(s) Sudhir C. Mehrotra and C. Edward Lan	8. Performing Organization Report No. CRINC-FRL-266-2
	10. Work Unit No. 505-11-16-07
9. Performing Organization Name and Address The University of Kansas Center for Research, Inc. 2291 Irving Hill Road-Campus West Lawrence, KS 66045	11. Contract or Grant No. NSG-1046
	13. Type of Report and Period Covered Contractor Report
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This document describes in detail the necessary information for using a computer program to predict distributed and total aerodynamic characteristics for low aspect-ratio wings with partial leading-edge separation. The flow is assumed to be steady and inviscid. The wing boundary condition is formulated by the Quasi-Vortex-Lattice method. The leading-edge separated vortices are represented by discrete free vortex elements which are aligned with the local velocity vector at mid-points to satisfy the force free condition. The wake behind the trailing-edge is also force free. The flow tangency boundary condition is satisfied on the wing, including the leading- and trailing-edges.

The program is restricted to delta wings with zero thickness and no camber. It is written in Fortran language and runs on CDC 6600 Computer.

17. Key Words (Suggested by Author(s))

Leading-Edge Separation
Aerodynamic Characteristics
Computer Program
Discrete Vortices
Iterations

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	128	$7.25